

[HOW YOUR WORLD WORKS]

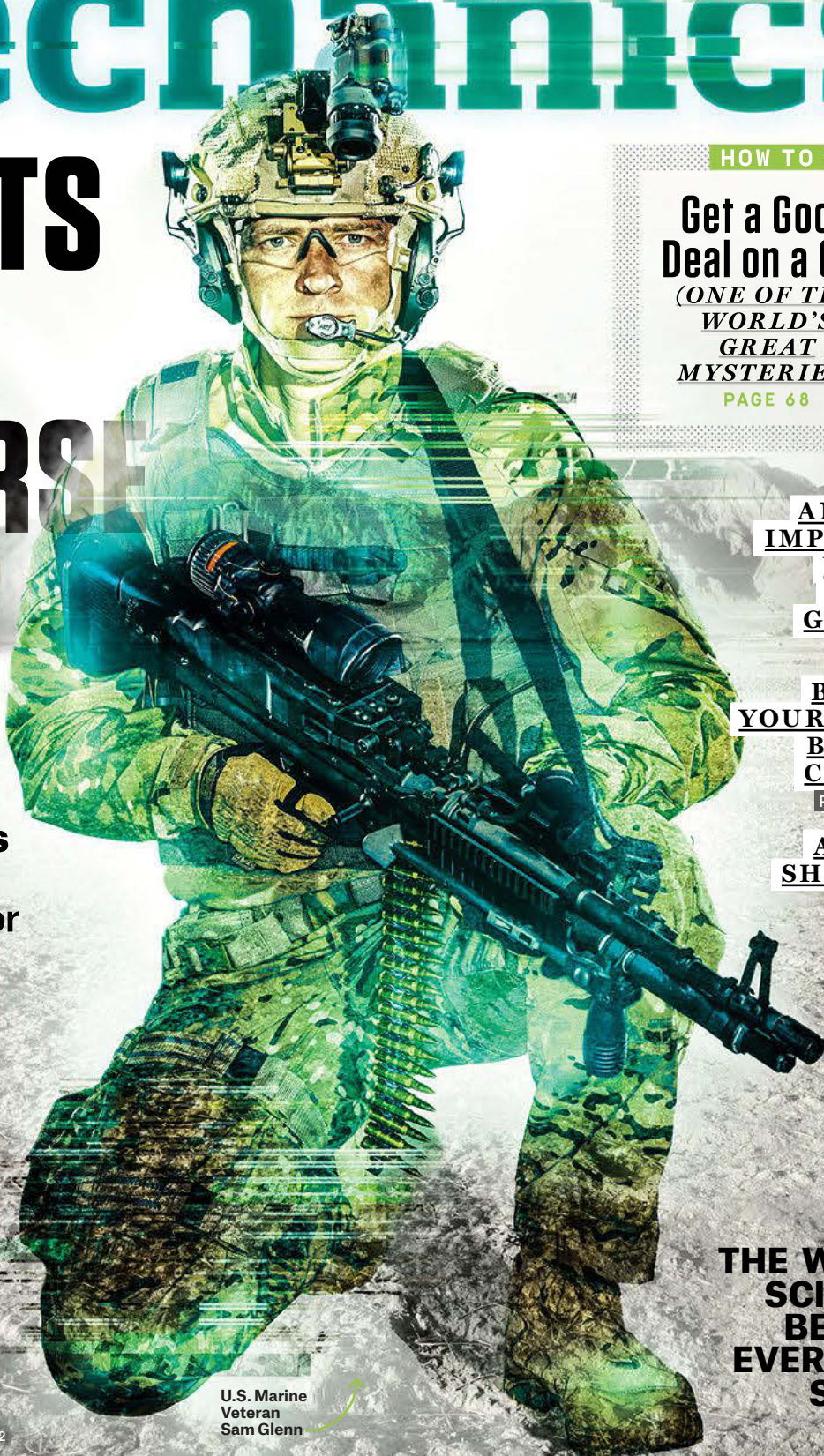
Popular Mechanics



SECRETS OF THE UNIVERSE REVEALED!

**How Holograms
Are Changing
the Way the
Army Protects Us
...And, Maybe,
Who You'll Vote For**

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U.S. Marine
Veteran
Sam Glenn

HOW TO

**Get a Good
Deal on a Car**
(ONE OF THE
WORLD'S
GREAT
MYSTERIES)

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GAME?**

PAGE 16

**BUILD
YOUR OWN
BOCCE
COURT**

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**AND...
SHARKS**

PAGE 17

**THE WEIRD
SCIENCE
BEHIND
EVERYDAY
STUFF**

 AMERICA'S
MAGAZINE
SINCE 1902

THE FU OF MU



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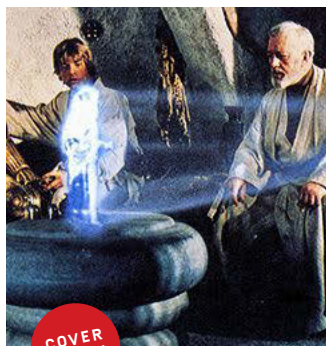
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Now we get to the really hard part.
BY JOSHUA FERRIS



ON THE COVER: Desert Storm veteran Sam Glenn photographed by Ian Allen and rendered as a hologram by illustrator Chuck Anderson.

From the Editor

A YEAR

Welp, that was fast. It's been a year since I got here. This year was a big deal for me, of course. But for Popular Mechanics? My first year was its 113th. I'm just the latest lucky sonofagun to be entrusted with a piece of its existence. We've done our best with this issue to continue its long tradition of explaining the secrets of the universe, and in fact (as you may have noticed on the cover) we're loosely calling this the "Secrets of the Universe Revealed" issue. Holograms (page 62), electricity (page 86), pirates' treasure (page 56), the science behind everyday products (page 88)—these are topics that could have been covered in almost any era, which is kind of cool. Still, I've been thinking about what it means to have this job in 2015 as opposed to, say, 1907 or 1964 or even 2005. Part of it is that you, as one of our millions of readers, can participate in ways that were impossible until a few years ago—and if there's one thing that's true of all our readers, it's that you are active participants. We can email each other, for example. You can watch videos on our tablet edition every month. We can read each other's tweets. You can enter our contests with the click of a mouse rather than by mailing a letter that would have been delivered on horseback.

The sum of these parts is that today a magazine can be brought to life. The paper magazine is still meant for, you know, reading, but it also becomes a vehicle driving you (we hope) to all the other channels that we create for your enjoyment and enrichment, including but not limited to:

- the astonishing number of great stories published on popularmechanics.com every hour of every day;
- our new podcast, *How Your World Works*, available on



They made me sit for a photograph the day I got the job. This is it.

the Panoply network (we'll have two more podcasts coming soon);

- videos showing you how to do projects or explaining the latest piece of technology, filmed in our new shop inside the Popular Mechanics offices; and
- @PopMechHome, the new social media presence of Roy Berendsohn, knower of all things related to home improvement.

All of this is, to me, both exciting and stressful. Why stressful? Because I've developed a terrorizing fear of failing to take advantage of these tools my predecessors would have loved to have. But fear is just motivation to act, so that's what we're trying to do. Let us know what you think. You know how to reach us. And if you don't, it's all here on this page.

RYAN D'AGOSTINO
Editor in Chief

WHERE TO FIND US

We're everywhere your phone is these days. You can keep up with all the happenings in the Popular Mechanics universe via:

Facebook: /popularmechanics
Instagram: @popularmechanics
Twitter: @popmech
Snapchat: popmech
Pinterest: /popmech
Tumblr: popmech.tumblr.com
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YouTube: /popmechshow

Get our attention with **#popularmechanics**, wherever hashtags are allowed.

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Ezra Dyer: @ezradyer
Alexander George: @engeorged
Thomas Houston: @thomashouston



THE EXPERIENTIAL CAR REVIEW: 2015 CHRYSLER TOWN & COUNTRY LIMITED PLATINUM

There will be no specs in this review. I have no idea how many seconds it takes for the Chrysler Town & Country to go from zero to sixty. But I drove one recently, and I know its suspension handles post-winter potholes with ease—you barely feel them. I know its V-6 engine can accelerate with surprising alacrity, even on curvy back roads, when you're trying to get your son to soccer practice on time. I know it can fit half the team after practice and that ice cream wipes off the floors easily, and I know my 5-year-old figured out how to fold down the third-row seats in two seconds. And I know that my wife, who is not a minivan person, sounded a lot like a minivan person when she said she wanted to take the Town & Country out to dinner with her friends. Minivans: suddenly kind of cool.

— R. D.

PopularMechanics
SINCE 1902

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Calendar

JULY & AUGUST

How to get the most out of your months.

JULY

WED 7/1

Start the month with a worn-out Arnold android. *Terminator Genisys* premieres.

THU 7/2

If you prefer your movies more socially conscious and sobering, buy advance tickets for *Cartel Land*,* out July 3.

FRI 7/3

Back-pocket trivia! The dog days of summer start today with the appearance of the Dog Star, Sirius, at sunrise and last until it descends again on August 11.

SAT 7/4

Barbecue conversation tip: Avoid complaining about how you're losing out on a free vacation day because the Fourth landed on a Saturday this year.



TUE 7/14

Keep an eye on the NASA Twitter feed as the New Horizons Pluto probe is expected to make its closest approach to the dwarf planet yet.

MON 7/13

Watch the best sluggers in baseball hit a few dingers out of the park in Cincinnati today for the Home Run Derby. Likely using one of the bats found on page 54.



SUN 7/5 - SUN 7/12

Don't know about you, but we're going on vacation this week.



THU 7/16

Apply an herbicide to the joints in your concrete walk where weeds have begun sprouting.



FRI 7/17

Paul Rudd is *Ant-Man*.

WED 7/22

SpaceX is overseeing the launch of NASA's Jason 3 satellite, which means another attempt to safely land the reusable Falcon 9 rocket after takeoff.

AUGUST

THU 8/13

Try to catch a flight out of town today, rather than tomorrow, if you can. Fridays in July and August are traditionally the busiest airport days of the year, even busier than the day before Thanksgiving.

SAT 8/8*

As good a weekend as any to paint the garage.

FRI 8/7

Kate Mara graciously leads us out of summer-blockbuster season in *Fantastic Four*.



WED & THU 8/12-13

The Perseid meteor shower peaks over these two nights. Wake up the kids and sneak out after midnight for the best look.



WED 8/19

Fix up the bocce court, if you have one. Build one if you don't. See page 101.

SAT 8/22*

Volunteer at a Habitat for Humanity site. Bring your teenager.

TUE 8/25

If it looks like you've got grubs—a few dark brown patches in your grass that peel off easily—apply a treatment now, while the grubs are still young and susceptible to pesticides.

FRI 7/3

THE MOVIE RECOMMENDATION: CARTEL LAND

Matthew Heineman's documentary covers the vigilante movement on both sides of the U.S.-Mexico border. The movie follows a small-town physician in Michoacán leading a civilian fight against an infiltrating cartel, and a self-appointed border-patrol unit in Arizona on the lookout for human-trafficking coyotes. It's a harrowing account of enforcing law in lawless land, and Heineman went under fire—filming through shoot-outs in Mexico—to show us.

SAT 8/8

HOW TO PAINT OUTSIDE IN MID-AUGUST

Try and do it on an overcast day, since direct sunlight dries paint too quickly, leading to blistering. If it's a bright day, start in the morning and follow the sun around the garage, painting in the shade where the sun has just been and won't be coming back.

SAT 8/22

HOW TO BOND WITH A TEENAGER

If your kid's summer job hasn't panned out, take him or her with you to a local Habitat work site. Volunteers can be as young as 16 and operate power tools. They'll learn valuable skills you don't necessarily pick up by delivering pizzas. Find a local chapter near you at: habitat.org/local.

The Reader Pages

The turning radius on Twisted Evil isn't ideal, but what's it matter when it looks this good?



PROJECT OF THE MONTH

A FOUR-WHEELED CHOPPER FROM AN AUTO-TECH EDUCATOR

Mike Fobes originally wanted a new Harley. He hadn't had a street bike since before his kids were born and now they were nearly grown. But his wife would not abide it. Rather than get into a drawn-out argument, he relented. He wouldn't buy a motorcycle. But he never said he wouldn't build one. And as a further concession to his wife's safety concerns, he decided he wouldn't even build a bike. Technically. Rather, his chopper would have four wheels. The 55-year-old master mechanic and auto-tech instructor looted a rotary engine from an old Mazda RX-7, put in a two-speed circle-track racing transmission, and attached two independent front wheels and two Avon 250 tires in the back.

For something that looks like it's straight out of hell,

Fobes's bike is appropriately named—he calls it Twisted Evil. With all the tweaks and improvements Fobes has put into the engine, it can get up to 200 miles per hour. Though he wouldn't try it. It's more of a show bike, with the turning radius constricted by the forks and rakes in the front end. It took him four years to build. After his wife saw the finished product, she finally caved, and Fobes went out and got a Harley. Twisted Evil remains a trophy of marital compromise.



READER TIP!

Coiled rubber compressor hose can be unwieldy and difficult to store. Install a vertical paper-towel holder to your workshop wall and slide the hose over it. The hose slides off easily to get to work, and goes back in place just as fast.

Terry Galbreath | Calhan, Colorado

THE VINTAGE TOASTER HALL OF FAME

Our elucidation of the greatest toasters of our time ("Great Unknowns," May) inspired some of you to write in with your own decades-old stalwarts that are still popping out consistently browned bread:



OUR CHOICE
The Toastermaster 1B14



The Sunbeam T-35
FROM Joe Schwert,
Andover, Minnesota



The Toastermaster Princess B102
FROM Adam Sawoski,
Southampton, Pennsylvania



The Delta Model 280 pop-down toaster
FROM Gene Stemmman,
Corvallis, Oregon

REMEMBER: We give \$100 for reader projects that we publish, and \$50 for original reader tips that we run. You can send both to editor@popularmechanics.com.

LETTERS



The Weather Channel's Jim Cantore in his natural state: elation amidst major climatic events.

FROM A FELLOW FAN OF THUNDERSNOW

You've given me yet another reason to renew my subscription. The Jim Cantore article ("The Storm Chaser," May) was outstanding. I thought I was the only person who was transfixed by thundersnow. Now, I'm sure that someone will complain about Jim's language and about the torn-up parking ticket, but to me, both of those elements helped to make one fascinating story. Readers met the real Jim Cantore, the guy we've been watching ever since he had hair. In addition to the meteorologist, we got to meet Jim the adopted child and Jim the divorced father of two children. Thank you for printing it. All of it.



BILL HARDING

Evans, Georgia

WHAT MAKES YOU THINK SOMEONE WOULD COMPLAIN ABOUT—OH.

I started reading the article on Jim Cantore with some interest. Then I hit the paragraph where he tore up a parking ticket. Is he that important? No one that arrogant is worth my attention. I don't care what TV show he's on.

William Clark

Springfield, Ohio



FLYING AND THE TERROR SPECTRUM

I am looking forward to the final installment of "Learning to Fly" by Joshua Ferris. I started

flying when I was 16, unfortunately running out of time and money before I was fully certified. Flying solo was without question the most terrifying and adrenaline-infused act I have ever done. And I've gone skydiving, towed a fish house down an icy hill in a two-wheel-drive Ford Ranger, and attempted many times to talk to women.

Joel Becker

Maple Lake, Minnesota

WE'LL RUN IT PAST THE NATIONAL WEATHER SERVICE

In "The Scientific Companion: Tornadoes" (May), you describe "three crazy ways to prevent tornadoes." Here's a fourth: How about a large formation of jet fighter planes flying through the Mach sound barrier counter to the direction of a forming tornado's spin? Instead of mothballing old jet fighters, we could give them a new life in protecting the homeland from nature.

Frank R. Tangherlini

San Diego

AN UPDATE ON SHELTERS

Our ranking of effective shelters to seek out in the event of a tornado ("The Scientific Companion: Tornadoes," May) reflected the recommendations of the National Weather Service before 2009, which have since been amended. Reordered according to the new recommendations, the best shelters are: basement, interior room with no windows, car, mobile home, then a ditch. Those who leave a mobile home or are outdoors should drive in a car to safe shelter. Our thanks to Dr. Thomas Schmidlin, a consulting meteorologist for Kent State University, for pointing it out to us.

THE CODE



Popular Mechanics has partnered with Ford to bring you The Code, a new editorial program inspired by the all-new 2015 Ford F-150, and the men who drive them. From the skills every man should have and the latest in gear to smart news and entertainment, The Code brings the spirit of "Built Ford Tough" to life.



THE HIGH FLYING LIFE OF AN AMERICAN TEST PILOT

For as long as there have been airplanes, we've needed test pilots — brave men and women who are willing to fly new and experimental airplanes to make sure they're safe enough for the rest of us. For this, the first in a series about Americans doing the most interesting and exciting jobs across the country, we go inside the cockpit with the lead test pilot for Virgin Galactic's SpaceshipTwo and president of the Society of Experimental Test Pilots, a man who has flown just about every kind of flying machine, from hang gliders to commercial jets to supersonic sub-orbital aircraft built to touch the lower reaches of space.

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The ultimate backup flashlight with a hand-crank, solar panel, USB charger, red emergency light



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An illustrated guide to fire making, first aid, shelter building, navigation and more



COBRA JUMPACK

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FIELD NOTES FNC-17 NOTEBOOK

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Great New Stuff

The things you need in your life this month.



Along with GPS tracking, the ST2 has built-in antitheft technology: Set the app to lock mode, and if your bike is moved, the back wheel locks up and the lights flash.

01

STROMER ST2 ELECTRIC BIKE

The ST2 is the moped of the twenty-first century, except it can go almost 30 miles per hour, has a range of more than 90 miles, and won't embarrass you when a friend sees you riding it. The digital display lets you regulate motor output and shows your speed and battery life, and you can use the app on your phone to track the bike or lock the wheels if you think it's been stolen. **\$6,990**

02

DYSON CINETIC BIG BALL ANIMAL VACUUM

Traditional cyclonic vacuums use centrifugal force to expel most dirt particles into a collection bin. Everything else is trapped in a filter. For the new Cinetic Big Ball, however, Dyson added a series of smaller, more powerful cyclones that remove all of the dirt on the first pass, which means no filter for you to clean. Not that you ever did anyway. **\$600**

03

BENJAMIN MOORE REGAL SELECT EXTERIOR REVIVE PAINT

For a long time the only way to change the color of the vinyl siding on your house was to replace it. Nobody made paint for siding, at least not in anything other than white, off-white, and light blue. But Benjamin Moore's new Regal Revive is specially formulated to stick to vinyl, goes on very easily, and comes in 335 different colors. Your neighbors will be jealous. **\$55 per gallon**

04

THE PUBLIC RADIO

This simple single-station FM radio is made out of little more than a Mason jar, an antenna, and a volume knob. It comes tuned to the frequency you preselect. All you do is turn it on or off and control the volume. **\$40**





JAKE GYLLENHAAL FOREST WHITAKER AND RACHEL MCADAMS

SOUTHPAW

DIRECTED BY ANTOINE FUQUA,
DIRECTOR OF TRAINING DAY
AND THE EQUALIZER

WRITTEN BY KURT SUTTER

BELIEVE IN HOPE. JULY 24

MANDARIN PICTURES

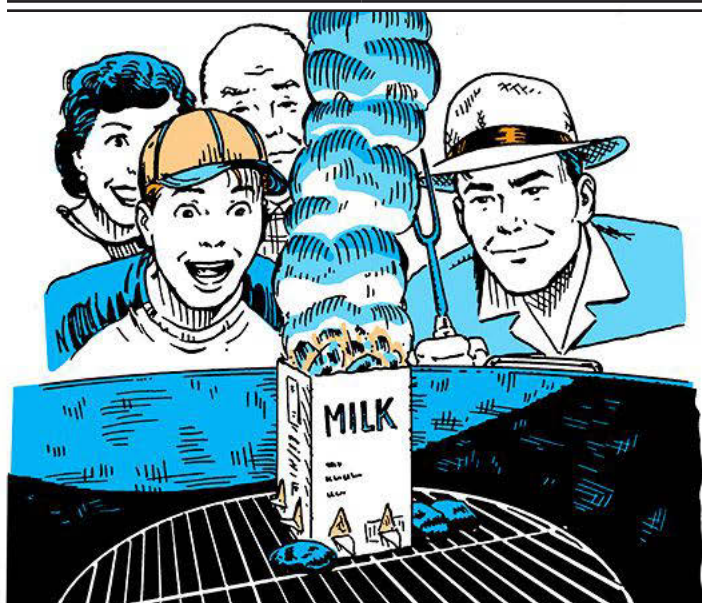
The Weinstein Company
A FILM BY ANTOINE FUQUA

Shop Notes

EASY
WAYS TO
DO HARD
THINGS

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Food Cartons Used to Ignite Barbecue

TO QUICKLY HEAT CHARCOAL for a small camp grill, improvise a chimney from a paperboard milk carton: Dry it out, cut off the top, and cut ventilation holes around the bottom. Stuff in paper scraps, then pour self-starting charcoal on top. Light the paper. For an easy-to-pack fire starter for picnics, fill the egg cups of a cardboard egg carton with charcoal. When ready to grill, put lighter fluid on the carton and light it.



Wooden Spoon Solves Kitchen Quandaries



Without a thermometer, how can you know when fry oil has reached the required temperature? Inserting the handle of a wooden spoon into the heated oil provides an indication: Slow-rising bubbles around the handle mean the oil is ready. When making pasta, a busy chef's pot often boils over. A wooden spoon balanced on the mouth of the pan retards the rising bubbles.

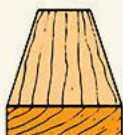
GUIDE TO WOOD GRAIN

The wide surface of a board and the growth rings of the tree it was cut from create an angle that is used to classify it.



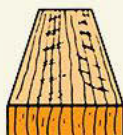
FLAT-SAWN

Zero to 30 degrees. Cathedral face grain.



RIFT-SAWN

Thirty to 60 degrees. Straight face grain.

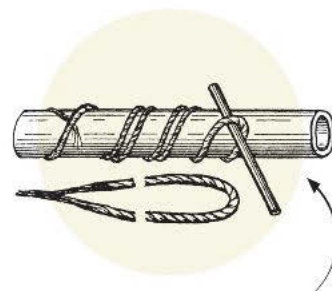
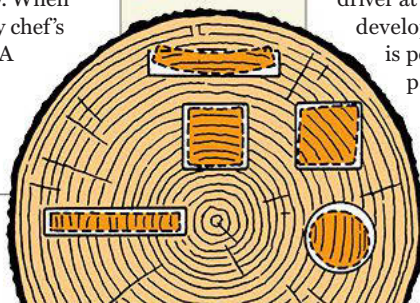


QUARTER-SAWN

Sixty to 90 degrees. Straight grain with flecking on face.

As wood dries, it shrinks in two dimensions: tangent to the growth rings and along their radius. Tangential shrinkage is more severe, so a board cut tangent to the rings is less stable. Here's how common cuts will shrink.

- ☐ fresh cut
- ☒ shrinking



FROM THE ARCHIVES (1908!)

Ingenious Improvised Pipe Wrench

Improvise a pipe wrench with a length of rope and a metal bar, like a crowbar: When a pipe needs to be tightened, fold a rope in half and tie the ends together. Wrap the rope tightly around the pipe, tucking the tied end under one of the windings to hold it in place. Thread the metal bar through the loop at the other end of the rope. Twist the bar and the rope tightens and twists the pipe.

Copper Wire Helps Wood Screw Grab in Stripped Hole

Remove the sheathing from a length of stranded copper wire. Insert the wire into the stripped hole and cut off the excess. Now insert the screw and begin driving it. It grabs, thanks to the wire.

Paint-Can Key Removes Excess Paint in Hard-to-Reach Areas

A standard paint-can key is not only more effective than a screwdriver at opening paint cans but it develops a burr on its end that is perfect for scraping excess paint from hard-to-reach places, like around the edges of a doorknob plate or escutcheon.



We are always looking for clever solutions to everyday problems. Email your shop notes to editor@popularmechanics.com and we'll pay \$50 if we print them.

Wooden Golf Tee Repairs Unsalvageable Hole

If the hole for a screw has become too loose but relocating it is not an option, fill it with a glob of wood glue, then hammer a wooden golf tee into the hole. Cut the tee flush to the wall. Let the glue set, then drill a new hole through the tee. Now to find a tee that can fix your swing.



Pouring Liquid From a Large Container, Spill-Free

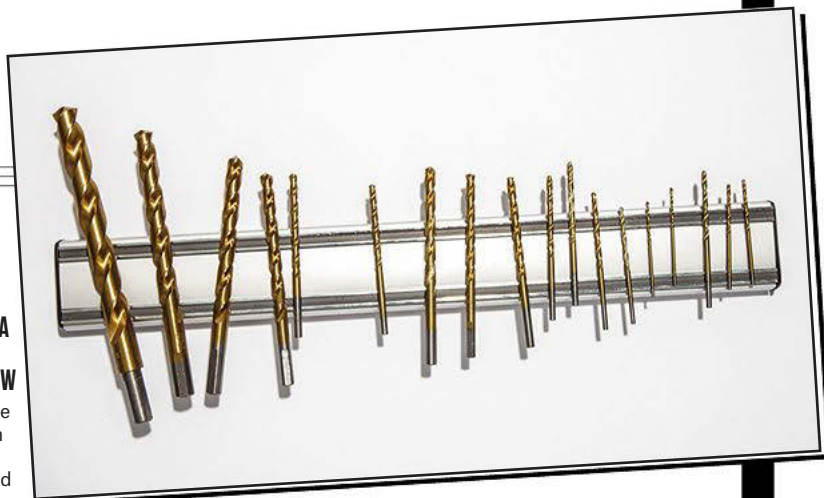
To pour liquid from a large container into the small opening of a second container without spilling it, hold a pencil across the opening of the large container with its point aligned to the small opening. Pour slowly and the liquid will run smoothly down the pencil.

Outdoor Plant-Watering System for Weekends Away

To slowly water plants while on vacation—without encouraging nosy neighbors—use a nail to poke a few holes in a liter soda bottle and bury it up to its neck in the ground next to thirsty plants. Fill it with water before you leave. The water will slowly release into the soil while you're gone. Don't forget to remove the soda bottle when you return.

HEAT REMOVES A PAINTED-OVER SCREW

Hold a spare screw with pliers and heat its head until it glows. Touch it to the paint over the stuck screw. The paint will burn away, making the screw easy to remove.

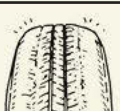


Magnetic Knife Strip Holds Drill Bits

Vanessa Beaty of DIYnCrafts.com suggests that a magnetic strip like that for storing knives, affixed to a workshop shelf, provides a convenient method for organizing drill bits and other small pieces easily jumbled in drawers.

Guide to Tire Wear

Rotating tires isn't enough. Abnormal wear patterns can indicate problems with the vehicle and the driver. Safety means knowing how to fix both (but you can blame everything on the vehicle).

TYPE OF WEAR	MAIN CAUSES	DRIVER ACTION	MAINTENANCE
 <i>Center</i>	Overinflation. Improper rim width. Aggressive acceleration.	Accelerate gradually, especially from a standstill.	Deflate to recommended tire pressure. Check rim width.
 <i>One-sided shoulder</i>	Improper alignment. Aggressive cornering. Faulty suspension.	Slow down when cornering.	Inspect alignment (camber) and suspension system.
 <i>Both shoulders</i>	Underinflation. Improper rim width. Aggressive cornering.	Slow down when cornering.	Inflate to recommended tire pressure. Check rim width.
 <i>Diagonal</i>	Improper alignment. Faulty suspension. Hard braking.	Avoid slamming on the brakes.	Inspect alignment and suspension system.
 <i>Spot</i>	Brake lockup. Faulty suspension. Improper mounting.	Avoid slamming on the brakes.	Ensure that tire is properly mounted and balanced. Inspect suspension and braking components.

CONQUER YOUR WORLD[®]

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HOW YOUR WORLD WORKS

SPECIAL REPORT | WEARABLES

WEARABLES: STUPID OR AMAZING?

Nearly every sport has a new device to attach to your glove, cap, shoes, or racket. They all claim to improve your game. We took a look at two of the most promising to find out if they can really help.

The first time I swung a tennis racket, the ball got stuck in the V of the handle, and I got humiliated. More recently I lined up a sure backhand winner only to send it out of the court and into the windshield of a passing car. I like tennis, but clearly finesse eludes me. So I was eager to try Sony's new Smart Tennis Sensor (\$200), a device the size and weight of a large acorn that snaps into the bottom of your racket and records data as you hit, then sends everything to a smartphone app for analysis—and a chance to improve.

To set it up, you remove the racket's end cap (currently Head, Prince, Wilson, and Yonex



▶ A COACH IN YOUR RACKET

Sony's sensor is the backseat driver of tennis, tracking and analyzing every shot. If you let it.

make compatible rackets), install a bracket in its place, then snap the sensor in. Your phone connects to it over Bluetooth. By measuring the vibrations generated by each shot, the sensor determines where on the racket head you contacted the ball and distinguishes eight different types of shots—including backhands, forehands, volleys, smashes, and serves—while capturing swing speed, ball speed, and spin.

I tried the sensor on a Wilson Blade 98S, a light, quick racket that I unnecessarily worried would be out of balance with the sensor attached. Over the hour during which my opponent and I took turns using the racket, his backhands seemed more effective than mine. Sure enough, when we isolated backhands on the app, his were far more consistent in speed and placement. (But I had more topspin.) You can also use the app's video feature to record your game. It automatically syncs the footage with each shot, so if you want to look at all of your dominant topspin forehands, you can. Generating a supercut of one type of shot is as simple as checking a box.

To find out what experienced players thought, I asked Sidd Thangirala and CJ Leong, of the New York University Men's Tennis team, to try

it. They found the sensor a bit obtrusive.

Unlike novices, who hold the racket high for greater control, advanced tennis players hold their rackets far down on the handle in order to generate more power, which meant both guys could feel the sensor jutting into their palms. On two-hander shots, Leong even managed to knock it out of the racket.

Clearly the device is better suited to beginning to mid-level players: pretty much anyone interested enough to take lessons. And that makes sense. The gap between the best college players isn't big. It requires an expert coach to navigate it. The gap between the baseline and a speeding windshield? An app can work wonders. — KEVIN DUPZYK

► THE ROBO GOLFER

IN GOLF THERE ARE mechanical players and feel players. I'm one of the latter. When I swing, I don't fight through a flurry of technical steps. I wait for the gentle tug at impact to tell me I've found the sweet spot, as if I were hitting a marshmallow. In my twenty years of playing, I've clung to the belief that overthinking strangles the fun out of the game. But with so many new swing-analysis gadgets being introduced, I finally gave in to curiosity.

Zepp (\$150) measures and records your swing through a small sensor that clips to the back of your glove and connects to a smartphone app. Input your age, height, grip style, and the make and model of your clubs, and after each swing you'll see a score and a 3D animation. The readout also shows your ideal club plane,

swing speed, backswing versus downswing tempo, and hip rotation. Unfortunately it can't account for ball flight or the important factor of head movement.

A few of my better shots received scores in the 80s. Some swings that registered in the low 90s, however, produced mediocre shots. This is not to say that the measurements were inaccurate, just that Zepp score and shot quality don't always correlate with my swing, which I don't bring back as far as would be ideal in the interest of accuracy. Zepp is probably more useful for very good players trying to improve minor aspects of their swing or for beginners whose habits aren't fully ingrained.

For any player the most useful aspect of Zepp is its record keeping. Along with weekly digests telling you how you rank against others, the app produces swing charts that can be shared, or kept to yourself if you don't want to lose Twitter followers. Each swing path can be compared to that of pro players

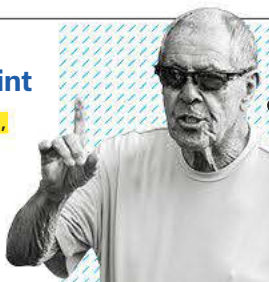


whose swings all score perfect 95s. (For now the app includes Brendan Steele, Ryan Winther, and Keegan Bradley, all young and slim, leaving portly players such as me longing for the addition of a Craig Stadler.) While it's fun to compare yourself to them, Zepp offers a narrow range of shots for the pros, all at full power. I'd be more interested in seeing how a pro gets out of a bunker with a difficult lie, and then practicing that.

Even so, Zepp did help my game, mostly because it brought my experiences at the range home. Hours of practice were turned into a series of charts and images to obsess over. I watched my swings over and over. And while I am still a feel golfer, at one point, about a month after I started using Zepp, I startled myself when a little voice inside my head said "hand plane!" on the downswing. Wouldn't you know, it turned out to be a great shot. — PAUL DEVLIN

+ The Counterpoint

By **Nick Bollettieri**, legendary tennis coach of players including Andre Agassi, Maria Sharapova, Jim Courier, and the Williams sisters



"I'm not interested in all the data you can give me. I'm not saying it won't be helpful to track what you're doing in practice, because they say what you do in practice will overflow into actual combat, but training is a lot different. There's no pressure on you.

"You can get too goddamn scientific: dip, shoulders turn, do this, do that. It's all bullshit. Just hit the goddamn ball."



THE SHARK CAM

If you want to see one of the ocean's fastest predators in action, just attach a camera to its fin. Simple, right?

BY ANDREW DEL-COLLE

Mako sharks don't make things easy on scientists. They're pelagic, for one thing, which means they live in the open sea. And they're fast. Faster than any other shark, believed to hit burst speeds of sixty miles per hour. Those factors have kept the mako largely unstudied, so much so that no one had seen live footage of a mako in its natural habitat. Paul Matusheski changed that.

Matusheski is the executive producer of *Monster Mako: Lightning of the Deep*, a show that premieres as part of Discovery Channel's cult phenomenon, *Shark Week* (starting July 5). To capture footage of the

makos, he knew he needed a better version of the fin-mounted camera and tracking systems used in the past. He wanted a device with forward- and rear-facing video cameras, red LEDs for unobtrusive night recording, a water-flow meter for gauging speed, a GPS tracker, a temperature sensor, an accelerometer and a gyroscope to record position, a computer, and a battery. He also wanted the unit to have a forty-eight-hour recording delay, giving the shark plenty of time to return to its natural behavior.

To help make the device, named Shark Eye, Matusheski turned to Evan Kovacs, director of underwater photography for

Woods Hole Oceanographic Institution. For Kovacs and his team, the biggest challenge was trying to achieve the complexity of what Matusheski wanted in just two months. It took a few modifications and hacks along the way—the water-flow meter, for instance, is just a repurposed wheeled pedometer from a Jet Ski—but they succeeded.

The next challenge was to find sharks. One of the benefits of the thousands of oil and gas rigs pumping away in the Gulf of Mexico is that they have created a flourishing underwater ecosystem that serves as a shark superhighway. After a mako is captured, the sixteen-pound camera is placed over its dorsal fin, and two cushioned bars are ratcheted down to hug the fin—a more humane and effective alternative to the traditional method of drilling holes through the fin. The process takes twenty minutes, start to finish, before the shark is released. The cameras are waterproof to about 3,280 feet, well beyond the suspected diving range of makos. After the seventeen-hour batteries are empty, the camera automatically releases and floats to the surface for pickup. It's just like the barrel scene in *Jaws*, only with scientific breakthroughs instead of impending doom.

HOW TO SPY ON A MAKO

The Shark Eye system allows scientists to record more and better footage than ever before.

A GoPro sits inside each front and rear camera housing.

The size of the rig required finding makos that were at least eight feet long.



Matusheski's team attaches a Shark Eye to the fin of a mako in the Gulf of Mexico.



SHARKSKIN IN THE HOSPITAL

If you ever decide to pet a shark, you'll notice that its skin feels smooth when you move your hand toward the tail, and rough toward the teeth. The scales, called dermal denticles, allow the shark to swim faster—and they might also be key to preventing hospital infections. Sharklet is a synthetic coating that mimics sharkskin to repel as much as 95 percent of bacteria. An adhesive film that you can mount to any surface (kitchen counters, handrails, etc.) is already available, but Sharklet's real objective is to protect hospital equipment. The company is currently testing a catheter, an endotracheal tube, and an intraocular lens, each of which is coated to repel the bacteria that cause dangerous complications such as staph infection. Which is not what you're at the hospital to get.

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HOW YOUR WORLD WORKS

TECH



FIG. A



FIG. B

+ THIS MONTH IN FOUND TIME

Since 1972, to account for the difference between the atomic clock and Earth's ever-so-slightly-irregular rotation, every so often a second is added to the world's official time. At midnight on June 30, enjoy the extra sleep.

fitness tracker and payment device developed with American Express), more than four years in, the technology hasn't taken hold. The concept isn't that radical: Instead of a magnetic strip, your phone uses near-field communication (NFC), a short-range radio frequency, to give your credit card information to the vendor. No signing a screen, no receipt to find in your laundry a week later and throw away.

I want this technology to work, and I couldn't understand why it hadn't, so for one week I committed to shop with only my phone. There is no directory of participating businesses, so I came up with a work-around. MasterCard's Nearby app catalogs "contactless retailers," stores that accept specially equipped cards for swipeless payment, and those stores usually have NFC terminals. With that as my guide, I used my phone to

< The traditional payment option (fig. A) is nearly as convenient as the modern one (fig. B), but much harder to keep organized.

pay at the drugstore, Whole Foods, Starbucks, and in a taxi from work. I even used the most convenient of payment methods at the least convenient of

places: the DMV. By the end of my experiment, the idea of reaching for my wallet and swiping a card felt slow.

So why aren't businesses incorporating such consumer-friendly technology? One reason is that they're not convinced that something better won't come along in a few years. "Merchants need to hear 'This is the last nickel you'll ever have to spend on a register,'" says Leon Majors, an analyst at Phoenix Marketing International who studies Apple Pay. "Some merchants haven't upgraded payment systems in twenty years." The other reason is that we aren't demanding it. Until we do, we're years away from being able to leave our wallets at home. At least not without a plan.

Paying with your phone in the current environment is like driving an electric car. You're not alone, and there is some infrastructure to support you, but before you head out, you need to know exactly where you're going. And you need to tell everyone you know just how much you're improving the world by doing it.

THE FUTURE HATES YOUR WALLET

Phones have already replaced cameras, alarm clocks, and those bulky old CD binders. Is the wallet really next? **BY ALEXANDER GEORGE**

I shouldn't be this nervous. But standing in line at the drugstore waiting to buy Speed Stick, I can't help it. Almost a dozen customers are behind me, and a good number of them would probably be annoyed to know that I intentionally left my wallet at home. All I have is my phone.

When I get to the counter and ask the clerk if I can pay with my phone, he shrugs, says, "You can try," and gestures toward the terminal. I hold my phone over it, press my thumb to the home button to prove I'm me, and the screen dances and confirms the charge to my American Express. The process is shockingly quick, and leads me to tentatively ask a question I will repeat many times over the next few days: "So I'm all set?"

It shouldn't be this way. Google Wallet came out when Obama was still in his first term. Apple Pay was announced last September. And despite the recent introduction of the Apple Watch and the Jawbone UP4 (a

HOW IT WORKS



1. When held within four inches of an NFC terminal, the phone loads your default payment card.



2. You confirm you're you with your fingerprint or passcode, and the app generates a temporary card number unique to the exchange.



3. That number is sent to your bank. After confirmation, the credit card company authorizes the transaction.

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A FEW QUESTIONS ABOUT...

MIND TRANSFER

The futuristic thriller *Self/less* (in theaters July 10) follows a dying man (Ben Kingsley) who pays to have his consciousness transferred into a new body—only to discover that it belonged to an Iraq war veteran (Ryan Reynolds) whose memories now mix with his own. Which is less crazy than it sounds: The idea of transferring consciousness has intrigued scientists for generations, and it may not be science fiction much longer. **BY TIM GRIERSON**

WAIT. WHAT?

Yep. Really. “It’s definitely going to take a lot of neuroscience and computer science to do,” says Anders Sandberg of the Future of Humanity Institute at the University of Oxford. “But from our perspective, it’s not that crazy.”

HOW WOULD THAT WORK?

It helps to think of a person’s soul as a collection of information, Sandberg says. The challenge is that our brains aren’t as organized as computers. “By midcentury we may have a way to copy information from our brains, but putting it into a bio-

logical brain is probably going to be very tough,” he says. “In a computer, you would store the data according to when it arrives. In the brain, it’s kind of mixed up.”

Memories are created by neurons, and those are connected by synapses. But memories move after they’re formed. As we sleep, events from the day shift to long-term memory. Retrieving them, or even tracking them all down, will prove far trickier than simply double-clicking on a file name.

OKAY, SO THIRTY YEARS FROM NOW.

Not everybody is as hesitant as Sandberg.

Sergio Canavero, director of the Turin Advanced Neuromodulation Group in Italy, plans to conduct a human head transplant in late 2017. He already has a patient: Valery Spiridonov, a 30-year-old Russian who has Werdnig-Hoffmann disease, a debilitating spinal condition that’s left him confined to a wheelchair.

DOES HE TRANSPLANT JUST THE BRAIN OR THE WHOLE HEAD?

The procedure, which he believes will take thirty-six hours to complete, will fuse Spiridonov’s spinal cord to the spinal cord of a donor body. Though many in his field—and the world in general—find the proposed surgery horrifying, Canavero remains unfazed.

IS THERE ANY CHANCE THE DONOR BODY WILL RETAIN SOME MEMORIES?

Canavero acknowledges that, as in *Self/less*, some crossover between the new consciousness and the old will occur. “The brain filters consciousness, but it also interacts with other parts of the body,” he says, citing research that suggests that memories and other behavioral programs could also be located in the heart and the microbiome. “So there will be an interaction in the new body,” he says. “There is no question about it. There will be interference.”

SHOULDN'T THAT WORRY HIM?

He believes the new consciousness will be able to sift through unwanted left-over memories.

HOW?

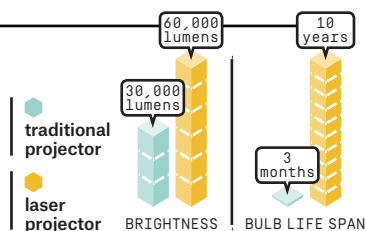
“The self—what you believe you are—can be easily adjusted,” Canavero says. “It’s very flexible.”

AND PEOPLE ARE REALLY GOING TO GO FOR THIS?

According to Canavero, it will require a world power like China or the U.S. to decide that this type of procedure is a priority. He compares it to the space race (and himself, quite confidently, to JFK). As for the risks, he says, “You have to consider that I am a scientist. I’m curious. I have answers I’m on a quest for. This is going to be huge.” Especially if it works.

HOW TO FIX 3D MOVIES

Merits aside, 3D movies have a problem. They’re way too dim. 3D glasses can block two-thirds of the light output of traditional projectors. The solution? Lasers. Laser digital projectors provide twice the brightness (and use half the energy) of xenon-arc projectors. Up to 4 million individually controlled mirrors direct the lasers, creating an image of unparalleled quality, color accuracy, and brightness. Currently, only a few theaters in the U.S. (including Paul Allen’s Cinerama in Seattle) have laser projectors but IMAX plans a nationwide rollout soon. In time for *Star Wars VII*, we hope.



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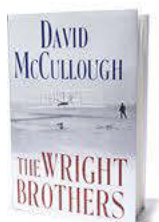
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THE ORIGINAL AIRMEN

For his new book, *The Wright Brothers*, Pulitzer Prize winner David McCullough pored over newspaper articles, photographs, and more than 1,000 letters to create a gripping account of Wilbur and Orville's quest to fly. He spoke to us about the brothers' training, innovation, and post-parade habits. **BY MATT GOULET**



POPULAR MECHANICS:

No one paid attention to the Wright brothers when they first started working on their airplane. Why do you think that was?

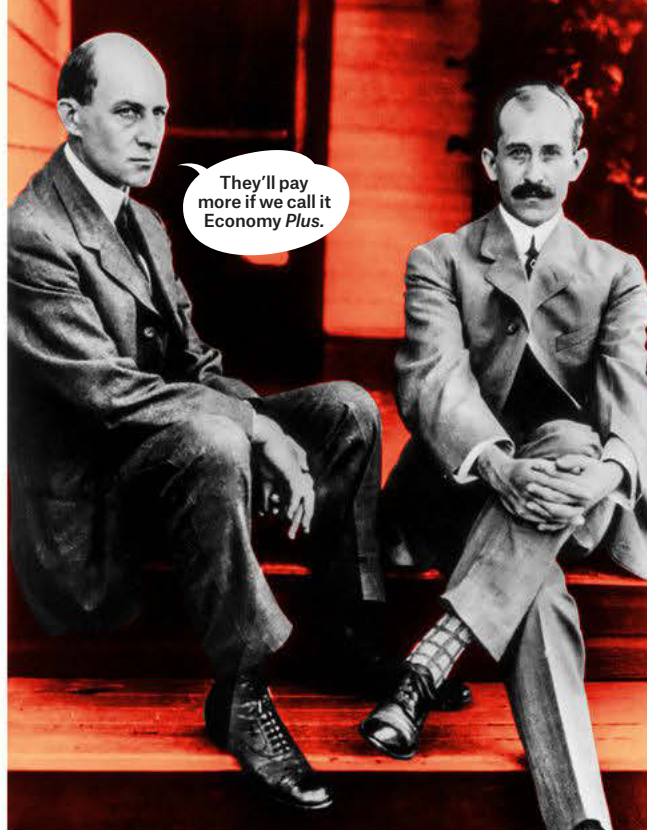
DAVID MCCULLOUGH:

The fact that they were so ignored is astonishing.

Ignored by the press, by serious scientific magazines, by the federal government, and by the newspapers right in their hometown of Dayton, Ohio. Nobody even bothered to go out and take a look. They did it all themselves. They didn't have any foundation backing them. They didn't have the facilities of some institution or corporation. They didn't have political contacts, or an angel funding their experiments. They were paying for it out of their own relatively meager earnings from a bicycle shop, and giving up a hell of a lot in life in order to do it. They were determined to succeed, and they did.

PM: Did their success change them?

DM: There was a huge homecoming in Dayton, celebrating their worldwide fame. For two days there were speeches and concerts and parades. And at every opportunity they quietly stepped away and went to their shop. I think that's about as revealing of the kind of people they were as almost any-



Wilbur (left) and Orville Wright on the steps of their Dayton, Ohio, home in 1909.

thing else that happens.

PM: So were they nerds?

DM: It's clear in the records that a great many people thought they were crackpots. Everybody loved to make fun of them. And that doesn't seem to have ever bothered them.

PM: You mention in the book that, after the Wrights were successful, even the Smithsonian was reluctant to give them the credit they deserved. Why was that?

DM: Out of pride in Samuel Langley*. The Smithsonian didn't want to give up on him as the first hero of flight. But eventually they came around.

PM: Were there other things the Wrights didn't get credit for?

DM: The propellers are a very big one, along with their original wing-warping system and their use of a wind tunnel. And nobody had ever built a motor out of aluminum before. Nobody had thought of it.

PM: And all of that was with no formal training?

DM: They hadn't gone to MIT, but they were brilliant. Wilbur was a genius. His letters and speeches were as good as anything being said by anyone. Take his speech before

the aerial club in Paris. He stood up there in front of these learned, sophisticated people and gave a speech, which he wrote himself, as good as could be written by any speechwriter at the White House. Better, actually. And here he's supposedly just a mechanic from a bicycle shop in Ohio.

PM: So much of the Wrights' correspondence informed the narrative of your book. When you think about the way we communicate today, as a historian, are you concerned about how we're going to be able to preserve these things for future generations?

DM: Nobody writes letters anymore. When they do write something, they write it in a kind of pidgin English on electronic devices. And we don't keep diaries. No one in public life would dare keep a diary anymore because it can be subpoenaed and used against you in court. On top of all of that, there's a concern about how long the electronic correspondence will last. There is a whole group of people at the Library of Congress currently worrying about this.

PM: Do you think Americans have a proper respect for the Wright brothers now?

DM: The usual picture of them is of a couple of bicycle mechanics from small-town America who got lucky and built an airplane. They didn't just get lucky. They realized that success didn't mean just creating a flying machine. You have to know how to fly it. Before the Wrights, it was all theory.

FAMOUS BEARERS OF WINGS



Airplanes



Birds



Angels



Hooters Waitresses

* In 1898 the Smithsonian contributed another \$20,000 to a \$50,000 War Department grant Langley received to build a piloted airplane called an aerodrome. The aerodrome crashed twice upon takeoff before the project was abandoned.

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HOW TO IDENTIFY A MICHELANGELO

Hint: Check the belly button.

MICHELANGELO COULD HAVE saved a team of experts a lot of time if he'd signed his work. Instead, earlier this year in England, those experts spent months studying two bronze statues of men riding panthers. The works were previously credited to a 16th-century Dutch sculptor, but last year a Cambridge University professor discovered a drawing of a similar panther and rider by one of Michelangelo's apprentices,

THE WISDOM OF MICHELANGELO

"He who is not able to work well for himself cannot make good use of the works of others."

which would indicate that he used one of his master's works as a model. It seemed like more than just coincidence, and upon further investigation, enough evidence was found to make a compelling case that the statues were done by the most famous ceiling painter ever to live. That conclusion will be defended at a conference on July 6. In case you want to judge for yourself, the sculptures are on display at the Fitzwilliam Museum in Cambridge, England, through August 9. We asked one of the investigators, Dr. Peter Abrahams, professor of clinical anatomy at the University of Warwick Medical School and coauthor of *McMinn's & Abrahams' Clinical Atlas of Human Anatomy, Seventh Edition* (which is way better than the first six), to walk us through the identifying details.
— SARAH Z. WEXLER

MUSCULATURE, PART I

"The triangle of auscultation. It's difficult to see, because you can't just flex it. Its existence here proves that, even if the sculptor used strong stonemasons for models, he must have dissected a body, since there were no anatomy textbooks at the time. Michelangelo had been doing dissections since he was 18."

NAVEL

"Many artists of the time rendered the belly button in their own distinctive way. Michelangelo's *David* has a skin hood over the top part of the belly button, and so do these statues."

NETHER REGION

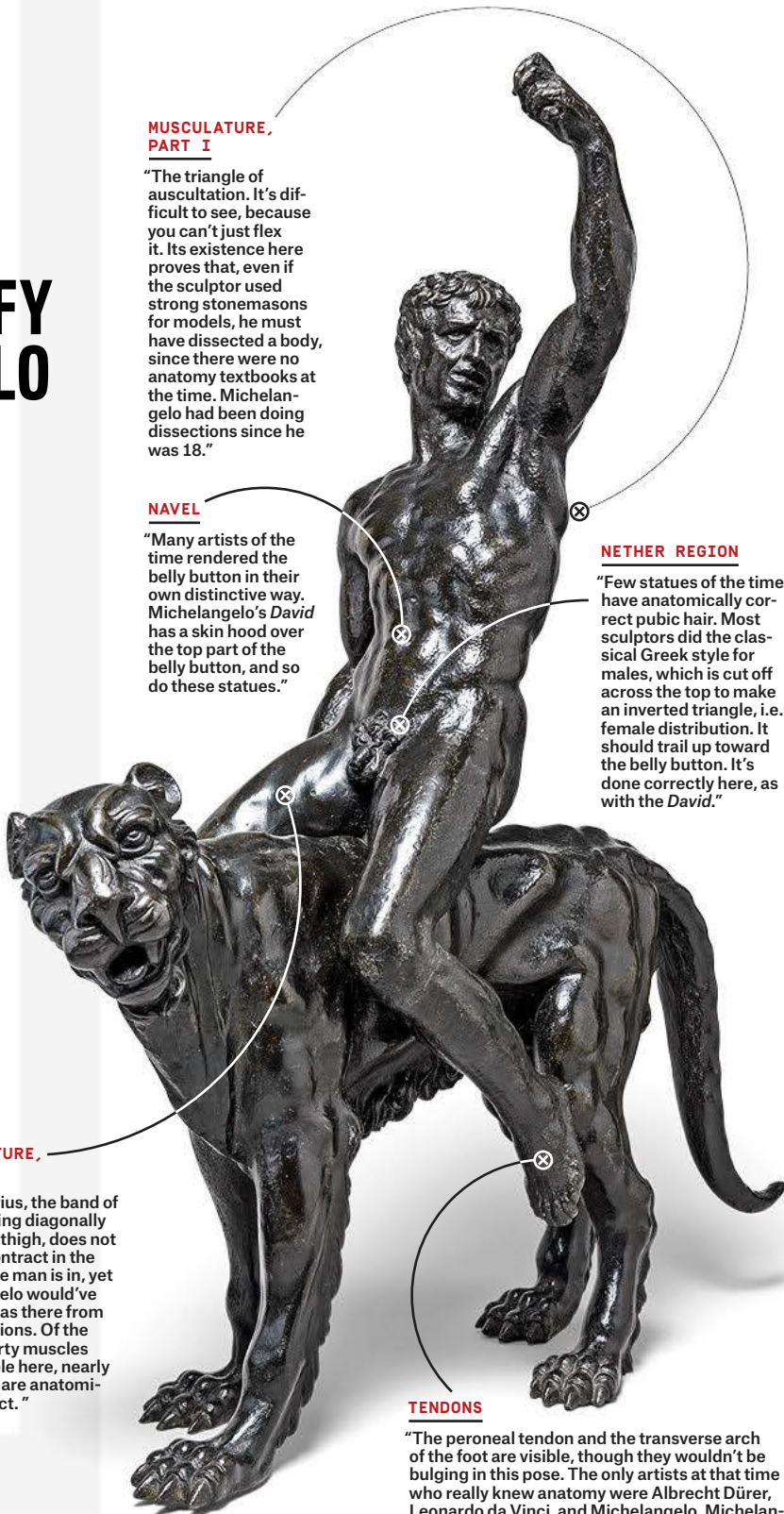
"Few statues of the time have anatomically correct pubic hair. Most sculptors did the classical Greek style for males, which is cut off across the top to make an inverted triangle, i.e., female distribution. It should trail up toward the belly button. It's done correctly here, as with the *David*."

MUSCULATURE, PART II

"The sartorius, the band of muscle going diagonally across the thigh, does not actually contract in the position the man is in, yet Michelangelo would've known it was there from his dissections. Of the thirty to forty muscles made visible here, nearly all of them are anatomically perfect."

TENDONS

"The peroneal tendon and the transverse arch of the foot are visible, though they wouldn't be bulging in this pose. The only artists at that time who really knew anatomy were Albrecht Dürer, Leonardo da Vinci, and Michelangelo. Michelangelo was the only one of them who did bronzes."



AN APPRECIATION: POST OFFICE HANDWRITING RECOGNITION



The Postal Service processes 1 billion letters, magazines, and envelopes a month. And no matter the variety of chicken to scratch out the address, nearly all eventually get to their destination. How? An Optical Character Reader takes a snapshot of every address, picks out the city, state, street, and house number, then compares those against a database to match the address with an eleven-digit ZIP code. Ninety-seven percent are read automatically. The other 3 percent get a fluorescent tag and are sent to a plant in Utah to be examined by an actual person with what must be incredible patience. — EBEN WRAGGE-KELLER

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ANYONE.**

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— J. from Orlando, FL
Stauer Client



This 4-carat stunner was created from the aftermath of Mount St. Helens eruption!

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On May 18, 1980, Mount St. Helens erupted, sending a column of ash and smoke 80,000 feet into the atmosphere. From that chaos, something beautiful emerged—our spectacular Spirit Lake Helenite Ring.

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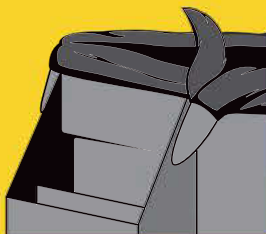


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THE MODERN MULE

A sturdy walk mower can take the exhaustion out of hours of yardwork. Buy accordingly.

BY BEAU GRIMMETT, DAVE NOONAN, and ROY BERENDSOHN

A mower may not snort and turn surly, but other than that it's not so different from the work animals our forefathers toiled behind in the fields. Depending on its temperament, a mower can make cutting grass easier or harder, and you don't really know which you're getting until you take your preferred model to some grass and let it show off. This is why we tested our self-propelled walk mowers on acres of pristine lawns belonging to the Charleston, South Carolina, parks department. We mowed cool-weather Northern grasses and tough Southern species. We mulched fallen leaves and weighed all the clippings from a 450-square-foot rectangle. We let five mowers out into their natural habitat to see what they could do. The mowers did not disappoint.



HONDA HRX217VYA \$700

Engine: 190-cc

Functions: Bags, mulches

Drive: Rear

Deck levers: Four

**BAGGED
CLIPPINGS:** 6.8 lb

Likes: Honda mowers are generally easy to use, and they deliver outstanding cut qual-

ity and bagging. The testers particularly liked this model's power, its dial-adjusted speed control, and its blade brake clutch, which can disengage the blade but leave the engine running. This allows the mower to move without cutting.

Dislikes: There is some difficulty in releasing the drive to turn around. You have to allow the mower to coast the last few feet before reversing.

HUSQVARNA HU700H \$380

★★★★★

Engine: 160-cc
Functions: Bags, mulches, side-discharges
Drive: Rear
Deck levers: One

BAGGED CLIPPINGS: 6.2 lb



Likes: This machine cuts well and bags about as much as the Honda does. Our testers unanimously liked its comfortable handle, single-lever height adjustment, traditional lever-operated drive control, and large rear wheels, which smooth bumps and gullies.
Dislikes: You lose a little maneuverability with the rear-wheel drive.

TROY-BILT TB230 \$300

★★★★★

Engine: 163-cc
Functions: Bags, mulches, side-discharges
Drive: Front
Deck levers: Two

BAGGED CLIPPINGS: 2.3 lb



Likes: Occasionally we like to bring in a mower that we tested years ago to see how it stands up to the new guys. We're pleased to report that the TB230 has withstood the test of time. It's still light and fast, with plenty of power.
Dislikes: The comb on the front of the mower deck doesn't seem to do much during either mowing or leaf mulching.

CUB CADET SC 300 HW \$300

★★★★★

Engine: 159-cc
Functions: Bags, mulches, side-discharges
Drive: Front
Deck levers: Two

BAGGED CLIPPINGS: 2.8 lb



Likes: This easy-to-use model has twin levers to raise and lower the deck, ball-bearing wheels that help it glide smoothly, and an angled gas cap that makes it easier to fill. And it cuts well.
Dislikes: There's a learning curve for the drive control, which you engage by resting your hands on the bar and walking. This was a four-star mower that lost half a star on this point.

CRAFTSMAN 247.377300 \$300

★★★★★

Engine: 159-cc
Functions: Bags, mulches, side-discharges
Drive: Front
Deck levers: Two

BAGGED CLIPPINGS: 4.4 lb



Likes: Essentially identical to the Cub Cadet, this mower gets high marks for the same features. It's a solid machine that cuts well and has enough versatility to see you through all three mowing seasons, from the first cut in the spring to bagging leaves in the fall.
Dislikes: The drive control takes time to master.

THE MODERN SICKLE

→ *The humble lawn mower blade is a masterpiece of metallurgy. The boron-alloy blades made by Fisher Barton, for example, can withstand smashing full-speed into a steel bar without breaking. But even the best blades dull eventually, and when they do, they waste horsepower, slashing grass rather than cutting it. To sharpen one, put on safety glasses and work gloves,*

then disconnect the mower's spark plug lead, remove the blade, and scrub it clean with a wire brush. Next, clamp the blade in a steel vise. Take several strokes on each cutting edge with a mill file, moving the file from the blade's back to its front. To make sure the blade is evenly sharpened, hang it on a nail. If it doesn't hang level, remove metal from the lowered edge until it does.

If We May...

EMBRACE THE ECCENTRIC LAWN PATTERN



Growing up, mowing the lawn was my job. Every weekend I trailed a bright-red Snapper mower around our quarter-acre yard. The work didn't take long—maybe an hour, tops—but I hated every minute, until I figured out a way to make things fun: patterns. At the time I still hadn't realized how dull regular-season baseball is. I watched a lot of it, and I saw no reason that our backyard couldn't look as good as Fenway or Camden Yards. I started out easy. One week of vertical lines, followed by a week of horizontal. No one complained, or really noticed, and, if nothing else, at least I was doing something good for the grass, since variety meant I wasn't running the wheels over the same suffering blades every week. After that I moved on to diagonals and then a checkerboard, which took more time (you're mowing the lawn twice, to get lines both vertical and horizontal) but looked fantastic. The trick is to stay true to a foundational line and not the shape of the yard. Any partial lines at the edges are absorbed by a final lap around the perimeter. From there I had to get creative. I tried a wavy line emanating out from the flower bed behind the back porch. That was a mistake. Then I tried a series of concentric circles starting from a tree in the middle of the backyard. That was not a mistake, but it did lead my neighbor to ask if I was getting dizzy. That's the only real challenge to this kind of lawn care. It opens you up to occasional ridicule. But it's terrific for boredom.

— PETER MARTIN



Best ~~WORST.~~ SUMMER. EVER.

New ways to survive the wildest outdoor season unscathed.



MOSQUITOES!

DEET is still the gold-standard chemical for hiding from mosquitoes, but the latest products also trick the bloodsuckers' sensory abilities. Carbon dioxide-emitting traps such as the **Mosquito Magnet Patriot** lure mosquitoes to their doom. There's also the new **Mosquito Bait & Kill** from Terminix AllClear, which coats plants and backyard surfaces in garlic oil and sugar for up to four weeks. (The sugar attracts them, the garlic oil kills them.)



POISON IVY!

Even if you tear it out by hand, poison ivy is likely to return. To kill a vine for good, spray it during its peak growth cycle, late spring and summer, with **Roundup Poison Ivy Plus Tough Brush**, which contains both glyphosate and a surfactant, which helps the glyphosate penetrate the surface of the leaves. If you can't find that, try **Ortho Max Poison Ivy & Tough Brush Killer Concentrate**. A greener option: Rent a goat. They eat the stuff.



WET CELLPHONES!

If your pool party is any kind of fun, someone is going to end up in the water with his cellphone in his pocket. To save it, turn it off and wipe it down immediately. Try placing the phone in a desiccant bag, such as the **Bheestie Bag**, which will remove moisture using the same technology as the Do Not Eat packets that come with shoes. Do not turn your phone back on for at least twenty-four hours. It'll short.



DRY BURGERS!

To keep precious fat from leaching out of your burgers and onto the coals, Josh Capon, chef of Burger & Barrel in Manhattan and six-time winner of the Burger Bash at the New York City Wine & Food Festival, recommends **loose patties**, a half-inch or more in thickness, using meat with a **75:25 lean:fat ratio**. About four minutes a side over direct heat. And stop playing with them.

THE PLAGUE, THE PRODUCT



Sharks: Shark Shield electrical-field generator **Mildew:** Jomax House Cleaner and Mildew Killer **Bird crap on the car:** 3M Synthetic Wax Protectant **Jellyfish:** Lanacane First Aid Spray **Out of beer:** Rum





DISASSEMBLY REPORT: CHAINSAW

MODEL: STIHL MS 362 C-MQ

PRODUCED:
VIRGINIA BEACH, VA.

DISASSEMBLED:
TORONTO

NOTES:

Jake Brandspigel, the Stihl product service supervisor who explained these parts to us, learned his job the old-fashioned way, by repairing lawn mowers as a teen. While pursuing a bachelor's degree in mechanical engineering, he continued working in shops. One day a Stihl representative on a routine visit called him out from under a mower and set him up for a post-college job. He's been at the company ever since.

NUMBER
OF PARTS:

297

TIME TO
DISASSEMBLE:
7 HOURS,
26 MINUTES,
40 SECONDS

- ① **GUIDE BAR:** Supports and guides the chain, and also feeds it lubricant via two small holes that release bar oil from the engine's oil pump.
- ② **SAW CHAIN:** The chain is what does the cutting, though it's actually more like shaving. Each link has a depth gauge that sets how deep it can reach into wood. One cutting surface, the side plate, slices down to the appropriate depth, and the other, the top plate, shaves wood away.

- ③ **CARBURETOR:** Delivers a mixture of fuel and air to the engine. This one optimizes the fuel-to-air ratio by continually changing the amount of fuel—in tests that last mere milliseconds.

- ④ **PISTON AND CYLINDER:** The chainsaw runs on a two-stroke engine: When the piston rises in the cylinder, it compresses fuel in the combustion chamber above it and creates a vacuum that pulls the next portion of fuel into the crankcase below. Combustion of the compressed fuel drives the piston back down, pushing exhaust out and forcing the fuel up into the combustion chamber for the next ignition.

- ⑤ **THROTTLE TRIGGER LOCKOUT:** Must be depressed before you can engage the throttle trigger to prevent *Friday the 13th*-worthy accidents.

- ⑥ **BRAKE BAND:** When you need to stop the chain immediately, the chain-brake safety feature tightens this band around the clutch drum, stalling the engine. The chain brake can be engaged in three ways: by releasing the throttle trigger lockout, by pushing

the hand guard forward, or if something jerks the saw, which is called kickback.

- ⑦ **REWIND STARTER:** When you pull the handle, a tensioned spring yanks the string back in. The resulting rotation engages the flywheel, turning the engine over.

- ⑧ **CENTRIFUGAL CLUTCH:** This allows the chain to remain still while the engine idles. It has two main parts: the inner shoes and the outer drum. The motor always turns the shoes, but at low speeds springs prevent the shoes from turning the drum. When the engine spins fast enough, centrifugal force overwhelms the springs and pushes them into the drum, pulling it and the chain along.

- ⑨ **MUFFLER:** Bolted to the side of the cylinder. Quiets what would otherwise be a very loud series of explosions, and contains superhot exhaust particles within a U.S. Forest Service-mandated spark arrester.

- ⑩ **HAND GUARD:** More protection from *Friday the 13th*-worthy accidents.

— KEVIN DUPZYK

A TIP ON DIFFICULT CUTS FROM A CHAINSAW ARTIST

➔ *Loggers and firemen make straight cuts. A chainsaw artist, on the other hand, often needs to create complicated swerves and twists. To cut a curve, such as when felling a tree with a bore plunge cut or during delicate pruning work,*

Jack McEntire, who makes extremely detailed totem poles, animals, and even human figures under the name Chainsaw Jack, recommends using a saw with higher torque and lower rpm, such as a Stihl, to prevent stalling.





Junior Ryan Lucier, front, and three other students replace the fuel line on the Camaro Z/28.

THE KIDS IN THE GARAGE

How to strip, repair, repaint, and rewire an old car—with help from an after-school auto club. Part six of a six-month series.

WHEN THE FREEDOM High School Auto Club in Freedom, Wisconsin, finally installed new engines in the 1974 Oldsmobile Delta 88 and a 1981 Chevrolet Camaro Z/28 we've been watching them restore, Ryan Lucier, a 17-year-old junior, worked with three other students to mount a fuel line to the Camaro's underside (see instructions, right). Lucier, now in his third automotive class, took his first class last semester and realized he loved it within the first week. He immediately dropped his art elective and added another auto-shop course to his schedule. Next year he plans to sign up for at least one more. "It gives me something to look forward to in the day," he says. There are far worse things to say about high school.



THE ESSENTIAL SUMMER BUG REMOVER

My dad taught the Freedom class before me, and one of the tricks he used to share is that nothing brings back the shine of a car like a clay bar. It's just a hand-size piece of clay that you can buy at any automotive supply store, but it works wonders, removing dirt and bugs embedded in the clear coat that remain after regular washing. Lubricate the car's surface with soapy water or spray wax, then scrub your front bumper or hood with the bar until the grit is gone. The clay should pick everything up, but it will dull the shine a bit, so afterward you'll have to wax and buff the surface. It's labor intensive, but the results are more than worth it. — JAY ABITZ, FREEDOM HIGH AUTO INSTRUCTOR

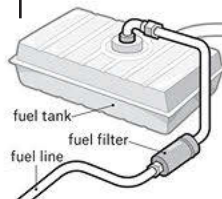
HOW TO

REPAIR A DAMAGED FUEL LINE

Tips from the Freedom High School Automotive Program

STEP ONE

Find the leak.



If a spot of gas appears on the driveway, you've got a fuel-line leak. To find it, jack up the vehicle and scan the steel fuel line that runs from your gas tank to the engine for holes. There will be multiple sections: for example, between the gas tank and the fuel filter, and between the

filter and the pump. Note, however, that fuel-line damage is usually caused by rust, so it is often found near the fittings that attach the line to the tank or the fuel filter. Use the location of the gas spot on the pavement to help you locate the damage.

STEP TWO

Remove the line.



Detach the damaged section by unlatching the clasps that hold the line to the underside of the car. Using tape or chalk, mark the path of the line and where the clasps should go. Most

late-model vehicles have brass fittings that connect sections of the fuel line, but some older vehicles use flexible hose instead. The former often require a tubing wrench and can be challenging to remove because of age and corrosion. When working on these, keep a can of penetrating oil such as PB B'laster handy.

STEP THREE

Buy a new fuel filter and line.



Lots of shops bend their own fuel lines, but you can also buy prebent line. While you're at it, pick up a new fuel filter. The only information the store clerks need to help you find both of these items is your car's vehicle identification

number, located on a label attached to the inner part of your door.

STEP FOUR

Install everything.



If possible, ask a friend to hold the line while you attach it, then use the old clips or a set of new ones to secure it to the car's underside. Make sure to connect it to the same components it was

connected to before. Also, bolt on the new fuel filter in the correct direction. You may have to note the direction before you remove the old one, or check for an arrow on the new filter. Now start your vehicle. Once fuel cycles through the system a few times, any problems should be obvious.

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Popular Mechanics' senior home editor solves your most pressing problems.

BY ROY BERENDSOHN



Q We have a nice cedar picnic table and bench set, but the tabletop is weathered and there are food and beer stains. The benches also need to be refinished. Can you give us some tips? ART L., EDEN, NEW YORK

A This is pretty straightforward. Begin with an application of an exterior wood cleaner that contains oxalic acid, such as Flood Wood Cleaner. Scrub the tabletop and benches with a coarse synthetic brush, being careful not to score the surfaces. You can use a putty knife or a painter's 5-in-1 tool (a hook-shaped putty knife) to remove any junk that's built up between boards. Now rinse everything and let it all dry.

Next, sand off splinters and flatten dents with 120-grit sandpaper. Brush off any dust and gently wipe the surface with a tack cloth (a sticky piece of cheesecloth sold in the paint-supply aisle of hardware stores and home centers). The last step before refinishing is to replace any rusty screws or bolts with some made of hot-dipped galvanized steel. These will have a thick zinc coating that provides

longer-lasting corrosion protection than the whisper-thin plating of zinc or cadmium you find on the bolts and wood screws that come in most home center bins. You can get hot-dipped galvanized fasteners on the Web or from old-fashioned hardware stores or industrial supply houses.

Finally, apply your finish. A semitransparent stain would be a good choice in that it will provide protection but also allow some of the wood grain to show through. Using a synthetic brush, apply the finish down the length of each board without stopping, so you don't get lap marks. If the picnic table sees harsh sun, you may want to apply two coats and reapply the stain every two to three years.

Q When my electrician brother came over to help me with some projects around the house, I noticed he makes holes in drywall with an awl, not

a drill. When I asked him why, he just said, "It's better." Is it?

CLINT M., LASALLE, ILLINOIS

A I think so. Contractors will often pack a heavy-duty awl (about \$10 at most hardware stores) with a full-length steel shank that's designed to be tapped with a hammer. A few light taps is all it takes to put a hole in $\frac{3}{8}$ -inch or even $\frac{1}{2}$ -inch drywall, and the awl's tapered shank will allow you to make holes of varying sizes.

Why is it better? It creates almost no dust, and it's useful for other unusual jobs, like digging out rusty staples. Also: It never needs to be recharged.

Q Our house has tiny black spots on its siding, and we've been told that this is caused by a fungus that grows in our flower bed's wood mulch. Is this true?

SUSAN P., HIGHTSTOWN, NEW JERSEY

A Yes. The spots are spores launched by tiny organisms known as artillery, shotgun, or cannonball fungus (*Sphaerobolus stellatus*). The spores stick to siding, cars, and lawn furniture and are impossible to remove without damaging the surface. They'll weather away eventually. To control the fungus, turn the mulch weekly with a garden rake. This disturbs the fungi formation and breaks the mulch down more quickly, making it a less attractive food source.



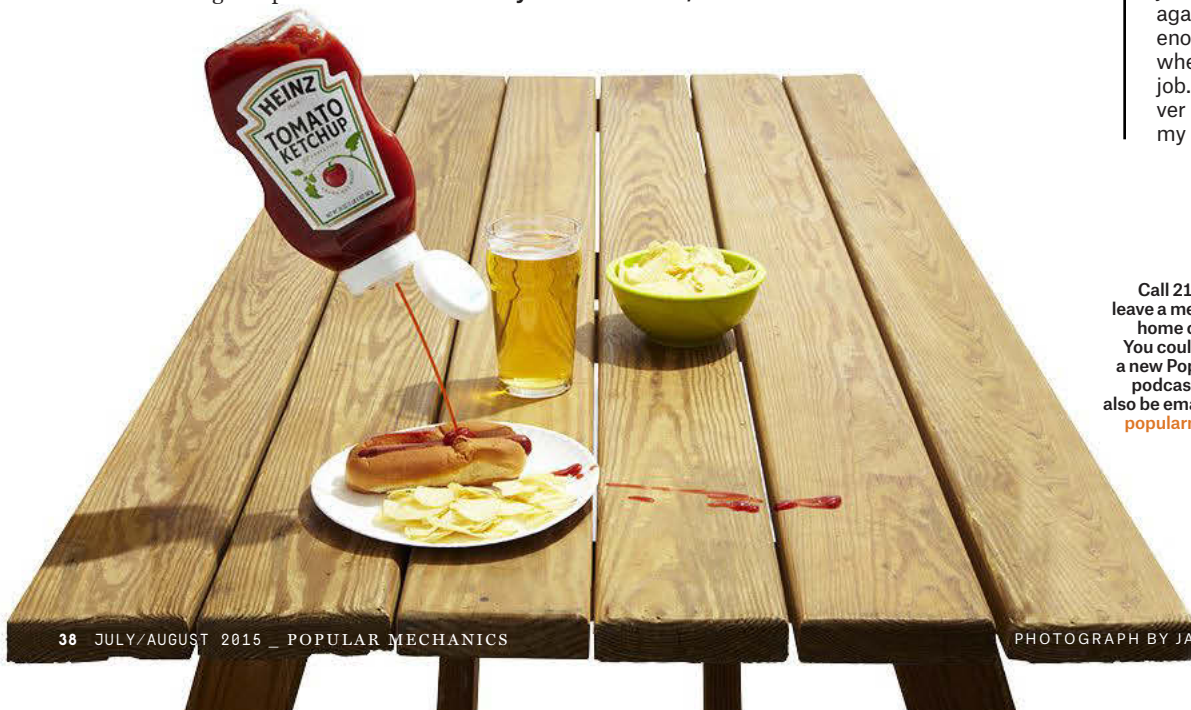
THE SILVER SHARPIE

When I started remodeling a 1950 Cape Cod home a couple years ago, I needed to make marks on rusty metal, cast-iron pipe, tile, and lumber so age-darkened it was nearly black. After a few annoying misfires with carpenter's pencils and pens, I came across a silver Sharpie. It was visible in low light and glaring sunshine on just about any color surface.

I suppose I could have just bought a whole pack of Sharpies in fluorescent orange, green, white, and black. If I ever remember to pick some up while I'm in an art supply store, I might do just that. Then again, I have enough to carry when I go on a job. A single silver Sharpie fits in my pocket.



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hands. Turn the watch over and examine the 27-jeweled automatic movement through the exhibition back. When we took the watch to George Thomas (the most renowned watchmaker and watch historian in America), he disassembled the *Magnificat II* and estimated that this fine timepiece would cost over \$2,500. We all smiled and told him that the Stauer price was less than \$90. He was stunned.

Try the *Magnificat II* for 60 days and if you are not receiving compliments, please return the watch for a full refund of the purchase price. The precision-built movement carries a 2 year warranty against defect. If you trust your own good taste, the *Magnificat II* is built for you.

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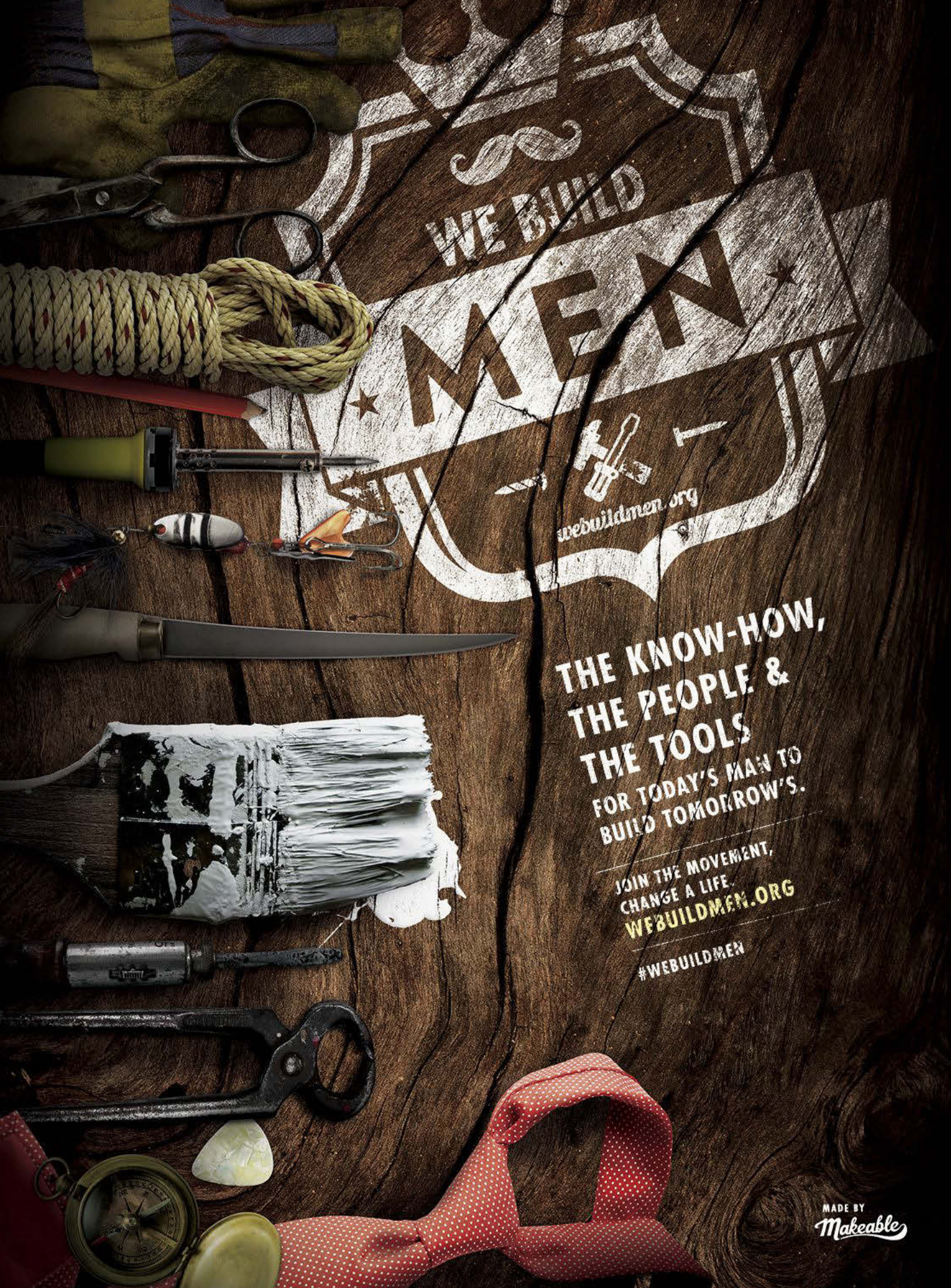
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PODCASTING

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The author prepares to record the new Popular Mechanics podcast, available on the Panoply network on iTunes.

THE PREREQUISITE:

Have Something to Say

► **TRUTH IS**, there are already entirely too many podcasts. For every engrossing show on iTunes there are another sixty bordering on torturous. But don't let that discourage you. *Your* podcast will be different. That's because you understand one very basic principle: You have to be interesting. And to do that, you have to know what you want to talk about, why you want to talk about it, and how you want to talk about it. This is important for more than just style—it also determines how you record. A show built around banter between cohosts puts a burden on studio equipment. A scripted show with one host requires tight editing, emphasizing software. We cover it all here.



Assembling Your Studio

► MICROPHONES

All mics do the same thing: translate the vibrations of your voice into electric signals. Condenser and dynamic microphones do this in two different ways, delivering distinct results. Condensers are less sturdy but more sensitive and require less

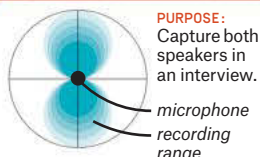
amplification—great for a home studio. Dynamic microphones are more durable and known to have a warmer sound, providing more of a traditional “radio voice.” How your mic connects to your computer is also important. No matter the type, the best mics use only an

XLR cable, an analog connector that provides the highest fidelity. These mics require preamplification and won't connect directly to your computer. USB mics usually have preamplification on board and plug directly into the computer, but their sound quality is slightly worse.

THE PRIMER: DIRECTIONALITY

Every microphone picks up sound within a specific spatial range, which is called its **directionality**. For studio podcasting, cardioid is optimal.

BIDIRECTIONAL, OR FIGURE EIGHT



PURPOSE: Capture both speakers in an interview.

CARDIOID



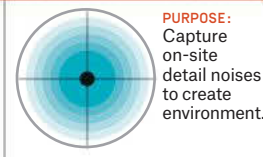
PURPOSE: Record one person's vocals while eliminating other noise.

SHOTGUN



PURPOSE: Targeted recording to eliminate on-site noise pollution.

OMNIDIRECTIONAL



PURPOSE: Capture on-site detail noises to create environment.



1. The Shure SM7B (\$349) is a sturdy, dynamic cardioid mic favored by lots of pros, including Marc Maron (that guy to the right).



2. For a dynamic USB option, the Rode Podcaster (\$229) is a quality cardioid mic designed with the home studio in mind.



3. The Blue Microphones Yeti Pro (\$250) is a condenser mic that offers outstanding versatility, with both USB and XLR connection options and the ability to toggle among four types of directionality.

► CONNECTING TO YOUR COMPUTER

Unless you're using only a single USB mic, you need a device that can route all your gear to your computer. There are various options, but a USB interface like the Focusrite Scarlett 6i6 (\$250, see photograph, page 41) has multiple XLR inputs and provides preamplification.

► ACOUSTIC HACKS

The goal while recording is to keep any sounds from bouncing off hard surfaces—walls, tables, your bowling-trophy collection—and into the mic. A few tricks can help.



A thick, lumpy blanket hung behind you is as effective as acoustic foam (that egg-crate-looking stuff). In a pinch, sit in front of a closetful of clothes.

2

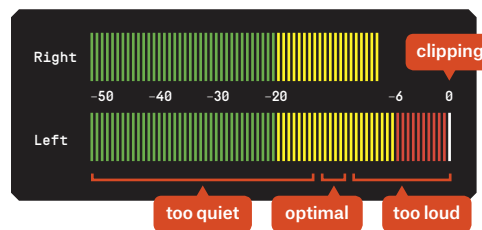
Recording Your Show

WHAT CAN GO WRONG—AND HOW TO FIX IT

► RECORDING LEVELS

Problem: Recording too loudly loses detail the same way too much light washes out a photograph. Recording too quietly does the opposite: When you crank up the volume to compensate, you'll hear unwanted noises.

Solution: Peak and loudness meters.



Peak Meter

A peak meter is the most common metering system. It measures the audio signal in decibels relative to full scale (dBFS). Zero is the maximum (which is why all the numbers are negative). Standard practice is to record between minus 15 and minus 12 dBFS.



Loudness Meter

The loudness meter is an emerging standard, designed to better account for how your ear works: At the same volume, deeper sounds hurt your ears less than high-pitched sounds. Use the Short Term reading on the meter and aim for minus 24 LUFS (loudness units relative to full scale).

► P-POPS, SIBILANTS, AND OTHER EXCESSIVE VIBRATIONS

Problem: Some letter sounds, like *p* and *b* bursts called plosives and exaggerated *s* sounds called sibilants, can't be taken out of a mix very easily.

Solution: Get gear to limit vibration. A shock mount suspends the mic on shock-absorbing springs, and a hoop-style pop filter kills bursts of air from your mouth before they get recorded.

► BACKGROUND NOISE

Problem: Ambient sounds, like that souped-up Harley down the street, can distract from your recording and be challenging to edit out.

Solution: Record at night, when there is less noise pollution. Unplug appliances. If you have to pick one, continuous sounds are less noticeable than intermittent sounds and easier to remove.

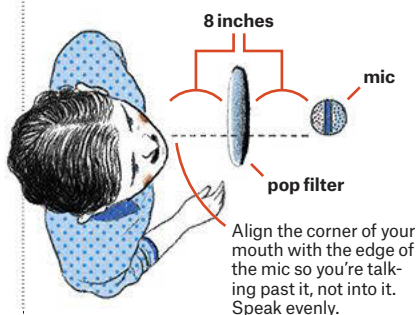


Shield the mic with an isolation box, a cube of foam with an open side for you to speak into. You can buy one or, better yet, make your own.



Worst-case scenario, do what reporters in the field have done for years: Record on your bed, under the comforter. Sweaty but effective.

THE PROPER RECORDING POSITION



IN CASE YOU INTERVIEW MICK JAGGER

Marc Maron has become a podcast star for conducting intimate celebrity interviews on his show, *WTF*, which takes place in his garage. Here's how.



I am almost always intimidated by guests unless I really know them. There's nothing wrong with being intimidated. You just have to be honest and true to your feelings. When I got to interview Mick Jagger, I knew that it was going to be limited. It's hard to figure out what to ask somebody when you have ten minutes. If you get too hung up on just asking questions, you're just going to get answers. To have a back-and-forth and feel engaged—that's different. So I sort of made it about me. I shared that I hadn't seen the Rolling Stones in thirty years, when Screamin' Jay Hawkins opened. And Mick remembered that show. He said, "You know, you should really see us more than every thirty years!" and invited me to a show on their current tour. It was a moment that was directly relational to me, and it was genuine.



Editing the Sound

THE DIGITAL AUDIO WORKSTATION

All of your editing will take place inside a digital audio workstation. DAWs allow you to bring in audio tracks, clean up their sound, and chop and rearrange them into a cohesive show. Depending on which one you use, their capabilities can be significantly more expensive. Here are three worth considering:

GarageBand

Does everything you need it to, and it comes free on every Mac. (Free, Mac only)

Hindenburg Journalist

Feature set is tailored specifically for radio or podcasting. (\$95)

Adobe Audition

Complicated to learn but extremely powerful. (\$20/month)

DON'T FORGET YOUR HEADPHONES

You can't edit well if you can't hear well, so get a pair of studio-quality monitoring headphones (pros call them cans). The industry standard is the Sony MDR-7506 (\$85). They're not too expensive, sound excellent, and are quite comfortable.



TIP!

EASY WITH THE EDITING • Don't remove every imperfect vocalization. No person speaks perfectly. Surrounded by computers, "ums" show we are still human. Long silences signal elusive truths. And if you laugh when you're editing, let the guest laugh as long as you did.



Posting Your Podcast

SELECT A HOST

Virtually every podcast is disseminated through iTunes, but it's really just a pointer telling the audience's comput-

ers where to go to download podcast files. It's up to you to figure out where to keep them. You've got three options.

Squarespace: Using a platform for building websites, such as Squarespace, can work. It's not specifically for podcasters, but it will host your files and isn't too expensive. (\$8/month)

Libsyn: A hosting service designed to make podcasting

painless. Libsyn facilitates submission of the show and offers metrics. Basic services are cheap, but scaling up can get expensive. (Starts at \$5/month)

Amazon Simple Storage Service:

If you strictly want storage space and you don't live on a server farm, you'll want real estate in the cloud. Amazon is one of the largest commercial providers of cloud space. (Price varies with usage)

MEASURING METRICS

Podcasting has one metric that matters more than all others: downloads. That sounds simple, but because of the way computers download audio files, it's not necessarily straightforward. You want to get your numbers from a reliable source. If you're not using a hosting service that offers podcast metrics, Podtrac (free) can get them for you at the cost of only a few tweaks to your hosting process.

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TechLiner® and Tailgate shown

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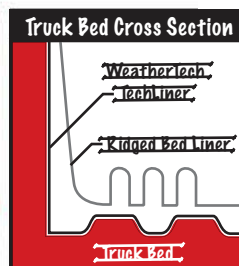
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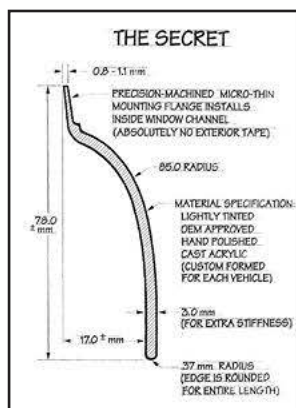
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WELCOME HOME THE BRAVE

A black silhouette of a soldier in full combat gear, including a helmet and backpack, walking towards the right. The soldier is positioned within the letter 'A' of the word 'BRAVE' in the main title.

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BY EZRA DYER

CARS



THE CAMARO AMERICA DESERVES

The sixth generation, arriving later this year, is less gruff while remaining just as gutsy. An exclusive first drive.

The Camaro has a big red button mounted to the top of the dash, an ominous mushroom that looks like it could start World War III. In fact, its purpose is to stop an out-of-control prototype. This is a 2016 Camaro, the all-new sixth generation, and it's not quite done yet—it's still in the oven, to the point that it needs a kill switch just in case the throttle software goes glitchy and sends you on an involuntary top-speed run. The car is also covered in camouflage, a precaution in case I sneakily remove the stickers that General Motors' security taped over my iPhone's cameras when I arrived at the car-maker's Milford Proving Ground. And oh, there is so much that I want to photograph. Is that a Cadillac CT6? Why is there a BMW i8 driving around? Focus, man.

The new Camaro doesn't look radically different from the 2015 model, but it's lighter, smaller, and more powerful than its predecessor. GM says the standard-issue SS—the first rung on the V-8 Camaro hierarchy—will beat the outgoing 1LE track rat on a road

PROTOTYPE STATS

- WEIGHT:**
 - 3,400 to 3,600 pounds
- ENGINES:**
(horsepower not finalized):
 - 2.0-liter turbo four-cylinder, 270 hp
 - 3.6-liter V-6, 330 hp
 - 6.2-liter V-8, 440 hp
- TRANSMISSIONS:**
 - Six-speed manual or eight-speed automatic

UP AHEAD The rarest cars in the world page 49 ► Summer toys! page 50 ► Reviews page 52



The 2016 Camaro prototype we drove was wrapped in camouflage to hide design details.

THE PETITION

LET ENGINES LOOK LIKE ENGINES.

► My first car was a 1985 Camaro. And not just any Camaro—an IROC-Z with the mighty TPI V-8 under the hood. TPI stood for Tuned Port Injection, and atop the engine block sat a gorgeous bundle of intake runners, one for each cylinder, looking like an aluminum arachnid caught feasting on its prey. These days popping the hood usually doesn't do much for you, because nearly every carmaker hides the engine beneath a big plastic cover. Ostensibly this is to quell noise, but really it's because it's easier to style a piece of plastic than it is to sweat the details. The plastic engine cover is a cop-out. Show us what you've got. Be real. If anyone needs an example, raise the hood on a Hellcat engine: all supercharger, no subterfuge.

course, and even the base four-cylinder will nail zero to sixty in the fives. But I'm not at Milford to do laps on the Lutz Ring track or rip burnouts on the Black Lake, GM's huge handling and dynamics pad. I'm here to drive a V-6 Camaro around the ride-and-handling loop, a stretch of road devised to torment suspension systems and the chassis engineers who tune them. Frost heaves, midcorner stutter bumps, large-amplitude rollers—the worst real-world surfaces are all represented. This is where GM decides to debut a Camaro? That's an interesting story in itself.

We already knew GM could build Camaros with race-car handling (Z/28) and ruthless drag-strip horsepower (ZL1). But over-the-road grace was never part of the deal. You didn't buy a Camaro because you expected it to smother an expansion joint the way a Cadillac could. Well, the new one might actually feel Caddy-like, given that it shares its Alpha platform with the ATS. The lightweight Alpha helps the Camaro lose as much as 300 pounds in V-6 cars and 200 in V-8s, which goes a long way toward addressing a major problem with the prior model: It was a zaftig chunk of car. Now, according to GM, we'll have the V-6 cars packing 330 horsepower and weighing in at around 3,400 pounds.

Engineers traded a traditional hand brake for a usable armrest and cup holders.

Before I get in the 2016, I drive a 2015 model around the loop to get a baseline on the existing Camaro's talents. And actually, the old porker still drives quite well—unlike the previous Ford Mustang, the Camaro had all-independent suspension the last time around. Nonetheless, when I hit a sixty-mile-per-hour dip, the impact causes my skull to bounce off the headliner on the rebound. Mass outmatches the suspension.

I climb into the disguised 2016 and head for the dip, wincing in anticipation as I hold the speedometer at sixty. The impact arrives, I'm compressed in my seat, and then the car goes momentarily light and simply continues on down the road. My head does not bounce off the roof. When we hit the stutter bumps, there's some chatter through the

steering wheel but the Camaro holds its line. There's still tuning to do, as signified by the big red panic button, but the initial impression is that the new chassis invokes a word that was never in the Camaro vocabulary: refinement.

However, GM didn't polish the personality out of the thing. Both V-8s and V-6s get optional active exhaust, and the owner can program the aggressiveness of the muffler bypass—from "stealth" to "constantly irritate the neighbors." The LED interior lighting has a demo mode that prompts the lights to change color in sequence around the cabin, a feature that is as awesome as it is totally unnecessary. And the roof has such a pronounced double-bubble design that cars with sunroofs will require a completely different flat roof panel. It would've been easier to just give all the cars flat roofs, but that wouldn't have looked as killer.

The new Camaro arrives late this year. And when it does, I'll have some unfinished business to attend to. The ride-and-handling loop was all very impressive, the new technology suitably sophisticated. But I can't wait to gun the V-8, drop the clutch, and welcome the sixth generation with a big, roaring burnout.



ON INSURING RARE FERRARIS



"The fact that you can get six Ferrari 250 GTOs on a transporter logistically has nothing to do with the fact that nobody in their right mind is going to put six Ferrari 250 GTOs on a transporter and move it one inch. Nobody in the world would have that type of coverage."

— **Tim**

McGrane
executive director,
Blackhawk Auto-
motive Museum,
Concours
d'Elegance trans-
port coordinator

"We have one guy who has a GTO, and we've shipped it several times. He likes to book the car on the same flight he's flying on and never insures it. He says, why do I care if the plane goes down and I'm on it? That's an interesting way to look at it when you have a \$40 million to \$50 million car, right?"

— **Martin E. Button**

president, Cosdel
International
Transportation,
which ships most
overseas entrants

PEBBLE BY THE NUMBERS



9 Most Concours Best of Show wins by a single carmaker: Bugatti.



36 Approximate number of Ferraris, a featured carmaker in 2015, expected this year.



200 Average number of cars shown on the fairway each year.



500 Number of truck drivers and staff fed at an annual BBQ hosted by a show regular.



1,893 Total years of Concours judging experience at last year's show.

THE WORLD'S MOST EXPENSIVE CAR SHOW

The annual Concours d'Elegance, held on the eighteenth fairway of Pebble Beach Golf Links every August for the past sixty-five years, gathers the rarest and most beautiful cars from around the world. This is how they pull it off. **BY ANDREW DEL-COLLE**

THE EVENT

► The Concours is on a Sunday and caps off Monterey Car Week, which consists of many geographically scattered functions—smaller shows, group drives, auctions, and races at Mazda Raceway Laguna Seca. Most cars arrive by Monday, and many participate in multiple events, requiring planning to keep Pebble's roads free.

SELECTIONS

► As soon as one show is over, the selection committee begins fielding applications for the next year's Concours. Accepted applicants are notified in April and begin working with one of two point people who coordinate national and international travel. It is the point person's job to make vehicle transportation as stress-free as possible for owners.

TRANSPORT

► U.S. entrants use trucking companies specializing in classic-car transport, private carriers, or single-car trailers. Some share trucks, and others will reserve an eighteen-wheeler just for their car. Overseas participants arriving by cargo boat or plane are first cleared by U.S. Customs as duty-free with a limited visitation time, then put on a truck.

SHOW WEEK

► During Car Week, U.S. show vehicles are kept in their transporters at a designated location near the eighteenth fairway that can hold up to 200 trucks. International cars, which do not have to stay on trucks, are kept at a separate International Entrants Tent by the tee box. The tent can hold roughly sixty cars and is guarded at night by an armed sheriff.

ARE WE THERE YET?

8,503

The most miles a car will travel to the Concours this year. It's a 1949 Aston Martin prototype from Singapore.

41

Average number of cars per show from outside the U.S.

Other countries 2015 entrants hail from: Japan, China, Australia, Argentina, throughout Europe.

THE OLDEST CAR AT THE 2015 CONCOURS D'ELEGANCE

1902 PANHARD ET LEVASSOR

OWNER: Peter Mullin, founder, Mullin Automotive Museum

To even have a shot at winning the Concours d'Elegance, every car has to be able to drive down Pebble's eighteenth fairway and across the stage located in front of the clubhouse. That shouldn't be a problem for this pristine French-made 1902 Panhard. The front-engine, chain-driven car has a Daimler 2.3-liter four-cylinder paired to a three-speed transmission and can still hit its original top speed of fifty miles per hour. Contemporaries could manage only fifteen to eighteen miles per hour.



2015 ARCTIC CAT WILDCAT SPORT LIMITED EPS

- ▶ **HORSEPOWER:** 60+
- ▶ **PRICE:** \$16,349

→ With a modest 700-cubic-centimeter inline-twin riding behind the seats, the Wildcat isn't one of those rides you see on YouTube ripping wheelies across California's Glamis sand dunes. It's more like the Subaru BRZ of side-by-sides, a machine that prioritizes balance over outright power. The Wildcat weighs only about a thousand pounds, and it has more than a foot of suspension travel front and rear—about the same as that of the desert-conquering Ford Raptor—which means it flits lithely across terrain that ought to make you feel like a carton of eggs that was dropped on the supermarket floor. The Arctic Cat should have no problem keeping up out on the trails, where its electric locking front dif-

TIP: This thing's so light that if you're going to jump it, you want to throw a couple of sandbags on the passenger-side floor to level your flight trajectory. Or find a suitably crazy friend to ride shotgun.

ferential gives you true four-wheel drive. And while the Wildcat is definitely biased toward fun, it retains some ranch-hand pragmatism with a two-inch receiver hitch and 1,500-pound towing capacity.



2015 KAWASAKI JET SKI ULTRA 310 LX

- ▶ **HORSEPOWER:** 310
- ▶ **PRICE:** \$17,999

Kawasaki is the godfather of personal watercraft, to the point that people assume the words Jet Ski are generic. They're not. This is what a real Jet Ski looks like, a green fiberglass bullet powered by a supercharged 1.5-liter four-cylinder that cranks out more horsepower than a nineties Corvette. With no transmission and no boost lag from the supercharged four, the 310 has the kind of throttle response normally reserved for, say, the Ferrari 458 Italia. That's not an exaggeration—an informal thirty-to-fifty acceleration test resulted in about 2 seconds, which is in the ballpark for a 458. The Ultra is also more than happy to chill. The stereo seems like a goofy feature, although cranking some Van Halen adds an element of fun to those no-wake zones.

EXORBITANT PURCHASE OF THE MONTH



The Zapata Racing Flyboard repurposes the workings of a personal watercraft such as a Sea-Doo or a Jet Ski to create the wildest experience you can have on the water. By using its onboard jet pump to power water through a hose connected to a separate wakeboard-size platform, the Flyboard shoots highly pressurized water through two nozzles on the bottom of the board to fly as high as thirty feet or even dive below the surface. After about twenty ugly minutes falling into the drink, I was soaring above the water on my rocket boots. It's a singular feeling, hovering ten feet above a lake while people on the beach frantically reach for their phones. The Flyboard ain't cheap (about \$10,000, plus the watercraft), but there are places around the country that offer lessons—which might make more sense.

2015 BRP MAVERICK X DS TURBO

- ▶ **HORSEPOWER:** 121
- ▶ **PRICE:** \$19,499

TIP: The Maverick comes with two keys: Gray limits you to 47 miles per hour, and black unlocks all 82. If you let a friend drive, start off with the gray key.



↙ Last spring I drove a 200-horsepower custom buggy in the Mint 400 desert race, and my codriver derisively referred to the side-by-sides as golf carts. As in, "Downshift to third, we've gotta pass another golf cart." However, there weren't yet any BRP Maverick X ds Turbos out there. The Maverick is the first turbocharged utility terrain vehicle, or UTV, with an intercooled turbo adding twenty horsepower to the standard 976-cubic-centimeter twin. With a Fox Racing

suspension providing up to sixteen inches of travel, it's actually kind of hard to jump the Maverick—the suspension just keeps drooping as the tires stay on the ground, like trying to pull a stubborn cat off a sofa. It's also the coolest looking side-by-side out there: The twin silencers tuck up under the rear deck like a pair of jet turbines, and the frame, springs, and A-arms are nuclear green. The intercooler housing, just behind the seats, looks like a malicious extraterrestrial's battle helmet.

How a Chicago Doctor **Shook Up** the Hearing Aid Industry with his **Newest Invention**

New nearly invisible digital hearing aid breaks price barrier in affordability

Reported by J. Page

Chicago: Board-certified physician Dr. S. Cherukuri has done it once again with his newest invention of a medical grade digital AFFORDABLE hearing aid.

This new digital hearing aid is packed with the features of \$3,000 competitors at a mere fraction of the cost. Now, most people with hearing loss are able to enjoy crystal-clear, natural sound — in a crowd, on the phone, in the wind — without suffering through “whistling” and annoying background noise.

New Digital Hearing Aid Outperforms Expensive Competitors

This sleek, lightweight, fully programmed hearing aid is the outgrowth of the digital revolution that is changing our world. While demand for “all things digital” caused most prices to plunge (consider DVD players and computers, which originally sold for thousands of dollars and today can be purchased for less), the cost of a digital medical hearing aid remains out of reach.

Dr. Cherukuri knew that many of his patients would benefit from, but couldn't afford the expense of, digital hearing aids. Generally they are *not* covered by Medicare or most private health insurance plans.



SAME FEATURES AS EXPENSIVE HEARING AID COMPETITORS

- ✓ Mini Behind-the-Ear hearing aid with thin tubing for a nearly invisible profile
- ✓ Advanced Noise Reduction to make speech clearer
- ✓ Feedback Cancellation eliminates whistling
- ✓ Wide Dynamic Range Compression makes soft sounds audible and loud sounds comfortable
- ✓ Telecoil setting for use with compatible phones, and looped environments like churches
- ✓ 3 Programs and Volume Dial to accommodate most common types of hearing loss even in challenging listening environments

The doctor evaluated all the high priced digital hearing aids on the market, broke them down to their base components, and then created his own affordable version — called the MDHearingAid *AIR* for its virtually invisible, lightweight appearance.

Affordable Digital Technology

Using advanced digital technology, the MDHearingAid *AIR* automatically adjusts to your listening environment — prioritizing speech and de-emphasizing background noise. Experience all of the sounds you've been missing at a price you can afford. This doctor designed and approved hearing aid comes with a full year's supply of long-life batteries. It delivers crisp, clear sound all day long and the soft flexible ear buds are so comfortable you won't realize you're wearing them.

Try it Yourself at Home 45-Day Risk-Free Trial

Of course, hearing is believing and we invite you to try it for yourself with our RISK-FREE 45-Day home trial. If you are not completely satisfied, simply return it within that time period for a full refund of your purchase price.

Can a hearing aid delay or prevent dementia?

A study by Johns Hopkins and National Institute on Aging suggests older individuals with hearing loss are significantly more likely to develop dementia over time than those who retain their hearing. They suggest that an intervention—such as a hearing aid—could delay or prevent dementia!

“Satisfied Buyers Agree *AIR* is the Best Digital Value!”

“I am hearing things I didn't know I was missing. Really amazing. I'm wearing them all the time” —Linda I., Indiana

“Almost work too well. I am a teacher and hearing much better now” —Lillian B., California

“I have used many expensive hearing aids, some over \$5,000. The AIRs have greatly improved my enjoyment of life” —Som Y., Michigan

“I would definitely recommend them to my patients with hearing loss” —Amy S., Audiologist, Munster, Indiana



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1

2015 LEXUS RC 350 F SPORT

→ I'm minding my own business on the highway when a pair of BMWs merge alongside, a 335i coupe nipping at the bumper of a previous-generation M3. As luck would have it, I'm driving a sport coupe of my own, so I flick the left steering wheel paddle to drop down a couple gears and get in the mix. But the BMW drivers don't acknowledge the white Lexus RC 350 that's attempting to join the party—no nod, no dismissive stomp on the throttle to signal presumed superiority. Lexus says that RC stands for "Radical Coupe," but the BMW guys don't see the RC as a machine in kind, and, really, maybe it's not. With F Sport trappings come aggressive styling cues, big wheels, and a sport suspension, but, alas, no extra power for the port- and **direct-injected 3.5-liter V-6**, which makes the same **306-horsepower** that it did at its introduction in the 2006 IS 350. To get power commensurate with the RC's carnivore styling, you need to step up from the F Sport to the full-on 467-horsepower RC F. That one is a bellowing V-8 anomaly in a world of small-displacement turbos, a car that feels more like the old M3 than the new M3 does. Sure, the RC F starts at \$63,325, but drive them both and you might agree that it's money well spent.

2

2015 VOLKSWAGEN GOLF SPORTWAGEN TDI S

→ Manatees don't really have any predators in the wild. If they did, maybe they would've evolved some muscle tone. Likewise, the diesel-powered Jetta SportWagen has had no competition in the U.S. If you wanted a small diesel wagon, this was your only choice. Volkswagen probably could've kept selling the Jetta regardless of whether it ever evolved or improved. Nonetheless, Volkswagen's replaced the Jetta with the new Golf SportWagen, which offers a slew of upgrades—more passenger space, more power, and better fuel efficiency. The Golf is also lighter and, in the case of the diesel, nearly \$2,000 less. With **236-pound-feet of torque** at only 1,750 revolutions per minute, the TDI burns rubber off the line. Paired to a six-speed manual, it's a combination that keeps you engaged with the business of driving—picking the right gear to ride that torque, short-shifting in pursuit of fifty-mile-per-gallon efficiency (easily attainable if you're cruising at sixty miles per hour). You can get the SportWagen with a gas engine, too, a nice little turbo four. But then you're tempted to compare it to Subarus, or perhaps VW's own Tiguan. Better to stick with the TDI, the star car in a class of one.

3

2015 KIA SEDONA

→ The Japanese minivans, the Honda Odyssey and the Toyota Sienna, are paragons of volumetric efficiency, with noses sharply angled to cram the maximum amount of interior space between the bumpers. Kia went a different route with the Sedona, allowing chief design officer Peter Schreyer to put style ahead of practicality—most notably in the form of a prominent hood. Somehow the look works, without seeming like it's trying to distance the Sedona from its undeniable minivan identity. But slide open those doors and it's minivan paradise in there, especially if you order the optional First Class second-row seats, which slide inward to clear the rear fender wells and offer leg-room Manute Bol would have loved. Of the standard cloth upholstery, Kia hilariously claims that its stain-repelling fabric will be "appreciated by anyone who leads an active lifestyle." Which, in minivan terms, translates as "My kids eat squeeze yogurts in the car." Besides the obvious utility factor, minivans have a secret benefit: Cops don't notice them, so you can regularly make use of the Sedona's **276-horsepower**. The **3.3-liter V-6** is actually a fun engine to take to redline. Just remember to tell the passengers to hold on to their yogurts when it's time for takeoff.

THE FIVE-WORD REVIEW



2015 ACURA ILX
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2015 VOLKSWAGEN TIGUAN 2.0T
Tiger + iguana? Tall Golf.



2015 MERCEDES-BENZ GL63 AMG
They AMG everything these days.

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THE LOUISVILLE SLUGGER

COMPANY:
Hillerich & Bradsby

LOCATION:
Louisville, Kentucky

FOUNDED:
1884

Joey Votto, the power-hitting first baseman for the Cincinnati Reds, specifically requests straight growth rings. In fact, he wants eight growth rings per inch on the maple billets that will become his bats, and those rings must be perfectly linear from end to end. Of the million three-inch-diameter billets that Hillerich & Bradsby, the makers of the Louisville Slugger, process each year for Major League Baseball players and beer-league softball players alike, fewer than 2,000 will meet the tight requirements to become a bat that satisfies Votto's demands. In all, only about 80,000 of those million billets will wind up fulfilling pro orders.

Bobby Hillerich, a fifth-generation woodworker and fourth-generation bat-maker—the son of the founding Hillerich turned the family woodwork-

ing business into a baseball bat company in 1884—oversees the wood-bat manufacturing for Slugger. He'll send photos of the selected billets over to Votto's people for his approval before they're turned. That kind of close development of custom bats for MLB players is a long-standing tradition between the company and the sport. When Ted Williams was the greatest hitter in the game, he used to come through the factory in Louisville and slip ten bucks to the guy who turned the wood, asking him to set aside certain pieces. Today Danny Lockett, who's been turning professional bats at Slugger for forty-five years, makes the final decision on which billets match the demands of which players. A ballplayer's request is usually born more from superstition and feel rather than any scientific or statistical reasoning, but the

company abides. Some guys like pin knots in the grain, others like a wide grain. Younger players prefer the density of maple, traditionalists go for the flexibility of ash. Lockett turns the bats in a CNC lathe programmed with over 2,200 bat styles, all developed with the major leaguers.

Hillerich gets to the factory every morning at five to get the machines running in time for production to start at six. He's always moving around the production floor watching over the machines from his great-grandfather's day working beside the modern equipment. Both the old and new are part of a process that elevates a piece of sports gear to a vital tool of the master—whether that's Ted Williams, Joey Votto, or you, in your Tuesday-night league—who will wield it at home plate.

—MATT GOULET

TREFULFING

Popular
Mechanics

ASH 113
MLB PRIME
LOUISVILLE SLUGGER

THE LAST LOST TREASURE

Using modern technology and old-fashioned sleuthing, two adventurers chase the wreck of a legendary pirate ship that vanished in the Caribbean more than three hundred years earlier.

BY ROBERT KURSON

CHATTERTON WAS IN THE STATES, so Mattera did the only thing he could think to do by himself in Samaná, a city in the Dominican Republic not far from where the *Golden Fleece* reportedly sank—he went to talk to old fishermen. He started near the cemetery, carrying a bottle of Brugal rum and a rusty can full of gasoline. Mattera handed the men his gifts and took a shot with his Spanish. “¿Dónde están los barcos perdidos?” Where are the lost ships?

The men asked what kind of ship he was looking for. “Pirata.”

The men smiled but had no answer. Mattera moved on to the next group of fishermen, and the next. One after another, they said, “Lo siento”—I’m sorry—but then he found an elderly man who began talking and waving his hands, and this is what Mattera took him to say: “I have a cousin in Rincón whose grandfather knew of a pirate ship in Samaná Bay.” The fisherman wrote a phone number on a piece of paper.

From his truck Mattera dialed the number and reached an elderly man who spoke passable English. Yes, the man said, he might know something about a pirate ship sunk in Samaná Bay. He gave Mattera instructions for a beachside meeting place at Rincón Bay, a forty-five-minute drive north.

Mattera knew Rincón Bay. Treasure ships were said to have sunk there. Rincón was equally beautiful and dangerous, a spot at the end of the peninsula where smugglers and killers do business in tiny inlets

too remote and too treacherous for authorities to patrol.

An hour later he pulled off the main road near Rincón and turned onto a gravel side street that led to the beach. In the distance a young man stepped onto the road and waved for Mattera to come through. In all likelihood he’d been sent by the fisherman, but Mattera slowed the Mercedes to a crawl to make sure. Shining his brights, he could see the man take a long drag from a cigarette, then flick the butt. When it landed, the street burst into flame, a wall of fire that blocked Mattera’s path. By instinct, Mattera slammed his car into reverse—he knew he was being ambushed—and as his tires dug into the gravel, six more men jumped into the street and began running toward him, waving clubs and knives and throwing flaming bottles. Mattera screeched backward about forty yards and spun his vehicle around, but when he shifted into drive, the transmission grinded and the Mercedes died. This was a place where men killed for ten dollars, so Mattera had a decision to make. He could try to restart the car. Or he could reason with the men the best way he knew how.

He pulled the emergency brake and opened his door halfway. Placing one foot on the road, he stood up into a crouch, lifted his T-shirt, and drew his pistol, then began firing rounds into the pavement in front of the



◀ John Mattera (left) and John Chatterton in the Dominican Republic in February 2009, closing in on their elusive quarry.

onrushing gang. The attackers skidded to a halt and rushed back toward the flames. Mattera looked for muzzle flashes—signs of return fire—but none came, and in just seconds the street was silent but for the barking of wild dogs. Breathing hard, he changed the magazine on his weapon, then got back in the car and got it started. If he left now, he could make it home before anyone came looking for revenge. And he would have done just that if he hadn't had a pirate-ship meeting to attend.



WHEN MATTERA FINALLY made it to the meeting, the old man told Mattera he'd find the pirate ship in Samaná Bay. Mattera had a good feeling about this. The fisherman hadn't asked for money up front, only for a piece on the back end. That was a good sign his information was solid.

When Chatterton returned from the States, he and Mattera loaded their boat and headed to the site the old man had identified. They stripped off their T-shirts and shorts and pulled on their dive gear, and before their two crewmen could wish them good luck they'd gone over the side. Landing on the soft, muddy bottom, the men checked their depth gauges—twenty-eight feet—a near match for the depth at which they expected the *Golden Fleece* to lie.

They'd brought along a handheld magnetometer, and as they moved it back and forth, the instrument began whistling into Chatterton's earpiece. Mattera could hear it through the water from three feet away. The men followed the sound until a shape materialized in the distance, a wall rising out of the mud and reaching up twenty feet from the bottom, something huge

and, with its stark right angles, man-made. They drifted over the top of the wall to investigate. Looking down, they could see rows of benches. Both Chatterton and Mattera had grown up in New York and knew what a ferryboat looked like. They could only hope this one had been empty, or at least that the passengers had escaped, before the boat went under.

Both men had seen human remains on shipwrecks through the years, and now they steel themselves to see more. Near one edge, Mattera saw what appeared to be a femur. He reached to move debris from the area, but a cloud of sand and mud exploded near his hand, and a row of razor-sharp teeth lunged toward his face, knocking him backward. He regained his footing just in time to see that his attacker, a four-foot barracuda, had turned back to come at him again. Legend had it that the barracuda in these parts were crazy, that they'd lost their minds by eating parrot fish infected with toxins—a disease called ciguatera—and that they would tear off a man's face if given the chance. Mattera did not wish to test the legend now. Swinging the giant lens from his camera, he hit the barracuda in the nose and sent it torpedoing out of the wreck.

"Sorry, buddy," he said. "We were just looking for pirates. And this sure as hell ain't no pirate ship."

A

BOUT SIX MONTHS LATER, Mattera and his fiancée, Carolina, waded into the water to the Zodiac carrying a picnic basket full of sandwiches, wine, water, and suntan lotion. On board they joined Heiko Kretschmer, a crew member who had already loaded his share of picnic treats: a hand-held metal detector, a shovel, and a hatchet. Mattera carried two cameras around his neck. Carolina wore a giant floppy hat.

Driving the Zodiac at tourist speed, they headed across the channel toward the eastern end of Cayo Vigia, a small island in Samaná Bay. They landed on a tiny section of sand, unloaded their gear, and did their best to look like they'd come from the nearby resort. Carolina posed for Kretschmer's snapshots, Mattera assembled a fishing pole. When they were sure no one was looking, they ducked into the dense woods and began hiking up the steep hill.

It took them twenty minutes to fight their way past tangled overgrowth and bird-size insects to a point more than a hundred feet over the water. Looking out over the channel, Mattera could see the world through pirate legend Joseph Bannister's eyes. In all the Caribbean there was no better place to careen a ship—to move it into shallow waters—or to win an unwinnable battle, like the fateful one he fought against the British that resulted in his ship sinking. From here pirate cannons could hit any target, but anyone shooting back would be doing it blind.

Kretschmer assembled the metal detector and put on the headphones. Running the unit over mud and brush, he listened for hits but heard nothing. The group pulled themselves through the overgrowth, trying to suck in the bits of fresh air that managed to penetrate the dense jungle. They kept moving, bent over and dripping sweat, all of it a fevered dream.

Kretschmer stopped. "I've got something," he said.

He moved the metal detector, slowly, over a patch of dirt and mud about three feet square. Beeps in his ear adjusted his aim until he arrived at a spot. "Here," Kretschmer said.

Mattera grabbed the shovel, Kretschmer the hatchet, and the men went to work digging on hands and knees. As the hole got bigger, Kretschmer pushed the metal detector into it to refine the dig. But no matter how much dirt they removed, there was more underneath. They kept at it for thirty minutes, chopping at roots, until the shovel finally collided with something solid at a depth of about a foot.

"Whoa, whoa, whoa!" Mattera said.

Now using a hand spade, Kretschmer chipped away dirt from the sides of the hole until a shape began to emerge, a little less black than the mud and as round as the top of the moon.

"There it is," Mattera said.

Wedge the hatchet behind the object, Kretschmer muscled and leveraged until the thing finally came loose. All three picnickers stared into the hole. Lying free at the bottom was a six-pound cannonball.

"The last time someone touched that was in 1686," Mattera said.



A firelock musket barrel like this one was one of the first signs the divers had found the shipwreck.



Divers found caches of beads pirates wove into their hair and beards.

M

ATTERA DASHED OFF AN EMAIL to Chatterton about the discovery, but Chatterton never got it. Driving the Range Rover for supplies, he'd hit a hole filled with jagged rock, tearing a gash in the sidewall of his tire. He managed to drive onto the beach, but when he tried to change the tire, the jack collapsed and bent, and the wheel sank up to its fender in sand. Chatterton checked his cellphone—no signal. It might be miles to the next town. He started walking.

Down the road he found four local men, one of them elderly, playing cards outside a small shop. They didn't have a jack, nor did they know where to find one, but they told Chatterton they would help. He tried to explain that the Range Rover was heavy, but they didn't seem to understand. Walking to the vehicle, the elderly man motioned for Chatterton not to worry.

The Dominican men studied the truck, muttering in Spanish too fast for Chatterton to understand. Soon they were gathering supplies: a large tree branch and a pile of rocks. I'm in the Stone Age here, Chatterton thought. The men went to work. Using improvised levers and fulcrums, and a big rock as a hammer, they bent the jack back into shape. Chatterton couldn't see how that would work, but soon the jack looked nearly new. When they got it under the truck, however, it gave way and collapsed again, this time beyond repair.

Chatterton began to thank the Dominicans and reached into his pocket, but none of them wanted his money. Instead, they went out collecting again, farther away this time, bringing back heavy palm branches and

HE PICKED UP
ONE OF THE PIPES.
BY ITS LENGTH AND
HEFT, HE THOUGHT
IT LOOKED LIKE A
MUSKET BARREL.





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A broken wine jug found on the *Golden Fleece*.



Another piece of evidence: a cannonball with English navy markings dug out of a nearby hillside.

giant rocks. Chatterton tried to explain that the jack couldn't be saved, but that's not what they had in mind. The men used the branches to dig a hole under the truck's strut assembly, then replaced sand with rocks. Chatterton grabbed his own branch and jumped in to help them dig. A space began to open under the flat, and the truck's frame came to rest on its rock support.

Now Chatterton could see the beauty of this plan. And it struck him that he'd often seen this kind of approach in Dominicans—that they rarely had what they needed, and often had nothing at all, but they didn't seem to notice that or at least be much bothered by it. Rather, they focused on what they did have—if not a jack then a branch, if not money then time—then cobbled together a solution, a different way of getting there. He'd long cursed their *mañana* culture, swore that these people were going nowhere because they didn't go at full speed, but as he watched the old man flip off the ruined tire and replace it with the spare, he could see what he'd admired about Dominicans all along—that they didn't worry for the future because they knew there was always a way to arrive.

The men shoved piles of rocks under the truck to give it purchase, then Chatterton backed it off the beach. He insisted they take the money in his pocket, about twenty dollars, and they did, *gracias, gracias*, then walked back to where they had come from, a place where they were dirt poor, able to figure their way as things came to them, looking happier than anyone Chatterton knew.

IN THE WATER, something caught Chatterton's eye—the rippling outline of a pile of stones, lying about twelve feet from shore. They had zeroed in on the site thanks partly to the cannonball. As he moved toward it, the shape came into sharper relief. It wasn't just a pile of rocks and stones. It was a pile of rocks and stones in the shape of a sailing ship, one big enough to cross oceans.

He and Howard Ehrenberg, another crew member, drifted over the pile. From above, they had no doubt this was ballast. And it was massive, about fifty feet long by forty feet wide. The shallowest part lay in just six feet of water, but much of the rest sloped downward. Chatterton checked the depth at the other end of the ballast pile. The reading on his gauge: twenty-four feet.

The men found artifacts right away: a paint can, a lawn chair, a combination lock. But for the first time, they weren't worried by garbage. They dug deeper. Near one end of the pile, Ehrenberg found a three-foot-long pipe, almost entirely encrusted in coral. Chatterton swam over and motioned—let me look.

Angling it into the sunlight shimmering down from the surface, Chatterton and Ehrenberg could see through cracks in the pipe's coral encrustation and down to the metal, which was not rounded like pipes should be, but forged into the shape of an octagon.

Chatterton left the pipe on the ballast pile and then swam to the surface. On the boat, dripping and clinging to the ladder, he called to Mattera. "John, you gotta get down there. You need to look at something."

Mattera was in the water minutes later. Hovering over the ballast pile, he could see five or six of the pipes. He picked one up. By its length and heft, he thought it looked like a musket barrel. Mattera had decades of experience

with guns. He looked closer. To him the object appeared to have been made in the late seventeenth century. That's when Mattera remembered what a seventeenth-century crew had reported back about the wreck of the *Golden Fleece* in 1686: There were muskets lying on deck.

Mattera snapped a photo of the artifact with his cellphone and attached it to an email he addressed to antique-gun experts and collectors he knew. In the subject line he wrote, "What does this look like to you?" He noted its dimensions and weight in the message field, but said nothing further. Then he pressed Send.

Hours later he received an email reply from a renowned expert in antique firearms. The object in Mattera's photo was a musket barrel. European. Dating from the late seventeenth century.

A holler went up from the Zodiac. The divers returned to the water and found more guns. The men could hardly contain their excitement. But Chatterton and Mattera knew these weapons would not be enough evidence. Even if they could be linked to Bannister's time, that didn't mean they had come from the *Golden Fleece*. An ironclad case couldn't be made based on just a half-dozen musket barrels and a theory. History would need better proof, something no one could argue with, especially with their competitors closing in.

What they didn't know was that they were about to come face-to-face with that proof, and in a form none of them ever could have imagined.



Robert Kurson's new book, *Pirate Hunters: Treasure, Obsession, and the Search for a Legendary Pirate Ship*, went on sale June 16. In this excerpt, the two main characters, salvage experts John Chatterton and John Mattera, close in on the greatest find of their lives—the wreck of the *Golden Fleece*, captained by a legendary pirate.



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BY DAVID HOWARD

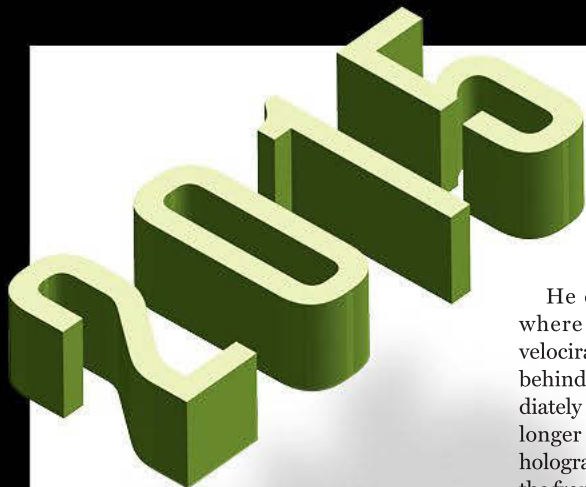
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HOLLOGRAPH
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Technology that allows people, places,
and things to appear in three dimensions is changing the
way our armed forces operate, the way
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Meet the people on the front lines of the other virtual reality.



THE DINOSAUR EXPERT

leans forward on a large L-shaped sofa in a room where blackout curtains erase the Beverly Hills sunshine. Two chandeliers gradually dim, and after a short silence a velociraptor appears on a stage scarcely twenty feet away, stalking back and forth, gliding on springy hind legs, tail whip-sawing. You can't hear any thump of footsteps, or anything at all, but still: The thing is not a flat image beamed from a projector but a creature with depth and heft and teeth. A physical presence.

Luis Chiappe, a balding man with a beard going gray, is the director of the Dinosaur Institute at the Natural History Museum of Los Angeles County, a 102-year-old institution that protects specimens dating back 4.5 billion years and that recently opened a 14,000-foot exhibition space called Dinosaur Hall. Over the past twenty years he has conducted fieldwork in Mongolia and Kazakhstan and many other places around the world. In the dark he is visible only by the reflection of the velociraptor in his glasses, so it's difficult to gauge his reaction. But he says, quietly, "That is amazing."

After a few moments a man named Alki David appears onstage, assuming a kind of master-of-ceremonies role. He has close-cropped graying hair and a pudgy, impish middle-aged face. The dinosaur dissolves, giving way to a series of celebrities alive and dead. Here is Ray Charles, fingers somersaulting across the keys of a piano, feet stomping. Here's Jimmy Stewart in a fedora. Eventually the lights rise, and David "Nuzzy" Nussbaum, who stands next to the couch through the presentation, asks Chiappe if he'd like to stand next to the dinosaur. Nussbaum is vice president of sales at Hologram USA, the company that last year began unleashing holograms into the world in various forms and is holding this exhibition for Chiappe today in a bid for his business.

"Sure," Chiappe says.

He climbs to the stage, where the newly conjured velociraptor begins prowling behind him, but he is immediately disoriented. He can no longer see the creature: The hologram is visible only from the front of the stage. He crab-shuffles uncertainly back and forth. Nussbaum coaches him to watch a monitor stationed to the side that shows the dinosaur, but Chiappe just keeps gazing around.

Nussbaum walks him back down and suggests that the museum could hire Hologram USA to set up a stage like this one to bring T. rexes to life in the Dinosaur Hall. "What's great about this," he says, "is that you could have kids at the museum take pictures with dinosaurs."

Chiappe considers this, but Alki David isn't done. "Bring up the secretaries," he says, grinning, into a two-way radio.

The lights dim again. Onstage appear two blond women in the midst of what might best be described as the latter stages of a gentlemen's-club-type presentation. An awkward quiet descends as the women writhe through the air. Finally, with mock outrage, David shouts, "Take them off!"

Outside, Chiappe looks dazzled, maybe a little bewildered, as he blinks in the sun.

1584 An Italian scientist named Giambattista della Porta, inventor of the camera obscura, first describes creating a three-dimensional, Oculus Rift-like effect in a paper titled "How we may see in a chamber things that are not." The viewer enters a darkened space and peers into a looking glass. The staging actually features a second reflective surface inside, set up so that when it is illuminated it reflects pictures of statues and furniture in a way that makes the viewer feel as if he were actually inside a room among full-size objects.

1858 A Liverpool, England-born engineer named Henry Dircks picks up the concept almost three centuries later after noticing that glass is both transparent and reflective. Through experimentation he finds that if he props a sheet of plate glass at a 45-degree angle he can bounce an image off of it that appears to be floating. He names the effect the Dircksian Phantasmagoria and

presents it to the British Association for the Advancement of Science.

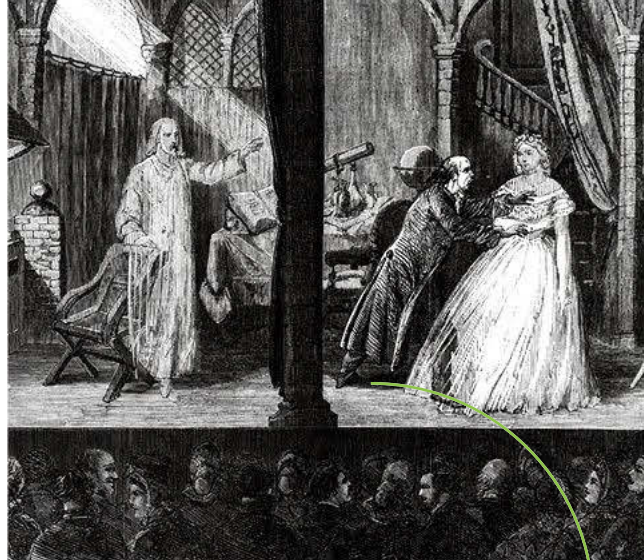
1862 Dircks has no luck selling his effect to theaters, but a scientist and lecturer named John Henry Pepper figures out how to modify the setup for the ghosts in a performance of Dickens's *The Hallowed Man*. Although he tries repeatedly to give Dircks credit, "Pepper's ghost" becomes a worldwide sensation, and the name endures to this day.

1969 Pepper's ghost turns up repeatedly at fairgrounds, inside haunted houses, and in magic shows—but hits its pop-culture apex when the Walt Disney Company deploys the effect in the Haunted Mansion ride at the Disneyland theme park in Anaheim, California, where riders see ghosts flying around the Grand Hall.



1977 George Lucas unleashes the first of his Star Wars movies, which features actress Carrie Fisher's character *Princess Leia* as a foot-tall hologram projected by a quirky droid named R2-D2. It is both a cool trick and a radical vision of the future—suggesting that we might one day drop in on each other in some beamed-in, particles-of-light, there-but-not-there fashion.

1996 Executives at the Ford Motor Company are frustrated by



the cost of creating prototypes for concept cars. They wonder: What if they could study a hologram of a vehicle instead? Ford approaches the MIT Media Lab, where Stephen Benton, who invented the rainbow hologram that appears on most credit cards today, works. The question leads three MIT researchers to form Zebra Imaging in 1996 in Austin, Texas.

Zebra prints 3D files onto a polymer sheet that resembles a photographic negative. Each sheet contains hundreds of thousands of hogels—short for “holographic element.” Think of hogels as similar to pixels, only each hogel is actually a single point of view of the image being printed. When light bounces off the polymer, the hogels act as tiny projectors, interfering with the light in a way that makes the image appear to rise off the surface and take on depth and breadth.

1997

German inventor Uwe Maass creates a three-dimensional experience like that in movies, only without the Clark Kent spectacles. “I started wondering, what kind of technology can I use to get rid of the glasses?” he says. He winds up with a twenty-first-century update on Pepper’s ghost, his stage set featuring a 3D projector and LED lighting—and to replace the glass, a special polymer foil material that’s invisible at a 45-degree angle but still reflects 60 percent of the light. The foil is only one millimeter thick, so it can be set up on a scale much larger than any sheet of glass safely could be, and can be easily rolled up and transported too. He debuts the setup, which he names Eyeliner, for an event by jewelry company Swarovski in Austria that features flying crystals. (See “The Resurrection Machine” for how it works.)

2006

The United States Army becomes Zebra Imaging’s primary customer. The Army orders a new kind of map—2 x 3-foot sheets that troops in the field can unroll and shine a flashlight on to reveal a hologram of the terrain in front of them. The map allows them to visualize exactly what lies ahead—how steep the topography, where they would be vulnerable to ambush. “Personnel rotated people through very quickly, and this helped orient them to the new digs,” says Rick Black, Zebra’s director of government solutions, who during a twenty-six-year Army career helped provide geospatial intelligence support for troops, including the new maps. “They were able to visualize in full 3D what their environment was going to be like.” Troops can also use the maps to consult with locals about where they’re going, and can

draw missions on them with dry-erase tools and later wipe them clean.

Multiple studies demonstrate that people process information more easily and understand it more quickly when they see it in three-dimensional form. The Medical Simulation Research Branch of the Army Research Laboratory published a study involving two groups of medical students that were each presented with materials on the anatomy of the human heart. One set depicted the valves and vascular structures in traditional textbook format, while the other showed the heart in holographic form. The students were tested after studying the materials, and the ones who had looked at holograms remembered more about the heart’s anatomy with less effort.

Zebra Imaging provided more than 14,000 holographic maps to American troops in Iraq and Afghanistan over a

2013

Maass, looking for a business partner in the United States, connects with Johnny Fratto, a talent manager who frequently appears on Howard Stern’s radio show. Fratto arranges a meeting with Alki David at David’s production studio. David instantly loves the hologram technology, but Maass worries that David lacks space for the Eyeliner setup. Maass “looks around and says, ‘There’s not enough room, you really can’t do anything,’” Fratto says. “So we’re standing there talking, and, I swear on my kids, all of a sudden the goddamn sledgehammer comes through the wall. Alki is on the other side of the wall with a sledgehammer.”

Hologram USA is born. “It’s very simple, age-old, snake-oil type of stuff,” David says. “But done with twenty-first-century technology, it’s mind-blowing.”



decade, and during that time the technology improved markedly, according to Zebra marketing manager Eric Doane. By the time the program wound down, the time required to create a map had dropped from five days to ninety minutes.

2012

Maass creates a hologram of the late hip-hop artist Tupac Shakur to appear onstage at the Coachella Music Festival with Snoop Dogg and Dr. Dre. The illusion is so lifelike that it makes Princess Leia’s hologram seem quaint in its grainy jitteriness. A video of the event generates 15 million YouTube views in forty-eight hours.

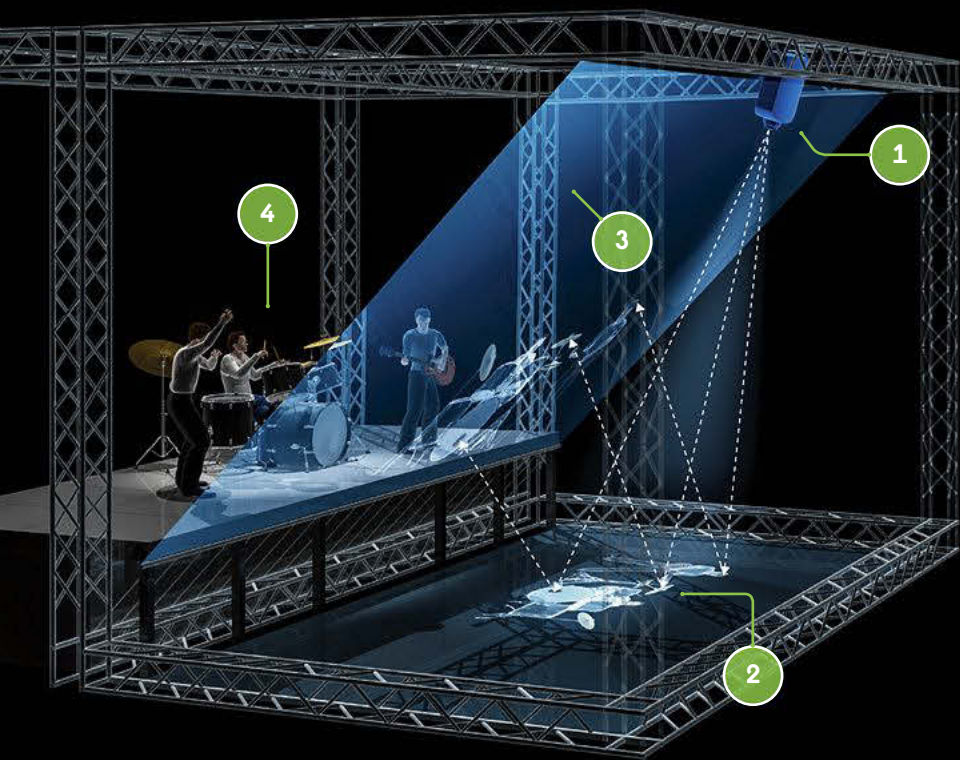
2014

Narendra Modi enters the race for prime minister of India. His polling numbers hover at around 34 percent, not a promising start. He hires Maass’s company, MDH Musion, and begins delivering speeches at as many as a hundred rallies at once by hologram. His three-dimensional doppelgänger speaks in more than 1,400 locations, reaching,

THE RESURRECTION MACHINE

A look at the technology and staging that could bring Hillary Clinton to seventeen campaign events at the same time.

Inventor Uwe Maass came up with a modern iteration of Pepper's ghost that creates startlingly real illusions. Here's how it works. — EBEN WRAGGE-KELLER



1 A high-definition Digital Light Processing projector hangs from the top of the stage set and projects a special 3D video downward in front of the stage.

2 A large reflective surface placed either in the band pit or in another low spot in front of the stage mirrors the image upward.

3 A sheet of polymer-foil material attached to the front and top of the stage and tilted forward at a 45-degree angle catches the image. The foil replaces the glass that was originally used in Pepper's ghost demonstrations—because it's safer and easily transported, and it eliminates shadows that glass throws.

4 The image appears on the stage and, because it is projected in 3D, looks like it has depth, width, and height rather than a flat, movie-screen look.

by some estimates, 14 million additional voters. “When people got word that he was projecting himself as a hologram to these places, he started to generate enormous crowds—30,000, 40,000 people per location,” says Nussbaum. Modi wins the election, garnering a rare plurality with 53 percent of the vote, and an Indian political observer opines that holograms call to mind “the Hindu mythology, where the God was omnipresent.”

In the United States holograms begin appearing in unlikely venues. In May a Michael Jackson hologram performs at the Billboard Music Awards five years after his death. Julian Assange, the WikiLeaks founder who has spent three years in asylum at the Ecuadorian embassy in London, appears in September in front of nearly 1,000 people in Nantucket, Massachusetts, as a hologram. Sitting on a stool identical to the

one his flesh-and-blood host occupies, Assange answers questions from the crowd and attempts, at the end, a hologram-to-human high five.

And in November Jimmy Kimmel hosts his late-night talk show in Los Angeles while simultaneously appearing by hologram at the Country Music Awards in Nashville, Tennessee. “We were aware that the technology was out there because of the cool pop cultural moments that had occurred,” says Doug DeLuca, co-executive producer of *Jimmy Kimmel Live*. Kimmel obviously couldn’t be in both places at once, so the hologram “seemed like an innovative and elegant solution.” Nussbaum says Hologram USA is building an installation for *Jimmy Kimmel Live* so the host “can beam people in for interviews at any time,” making him the first major television entertainer to embrace the technology.



installations. (The Apollo did not reply to an email seeking comment.) He recently reached agreements with the estates of Ray Charles, Liberace, and Buddy Holly, among others, to create live performances. Liberace’s estate was the first to sign on for appearances at a Las Vegas site to be announced. “The show will have all the glitz and glamour and razzle-dazzle of a real Liberace show, with the jewels and cars and showgirls,” Nussbaum says. And the show will be interactive—if someone hollers out a request, hologram Liberace can (if it’s in the preprogrammed database) play it. If someone in the audience is celebrating a birthday, hologram Liberace can—through some technological sleight of hand Nussbaum declined to reveal—invite her onstage, kiss her on the cheek, and hand her a bouquet of flowers. “They will be real flowers,” Nussbaum says.

Hologram USA licensed its technology



2015 David says part of his vision for Hologram USA is that no celebrity ever has to die. The company is working on deals with major theaters—Nussbaum mentions the Apollo in New York City as an example—to create permanent

to Universal for a ride that opens this summer at Universal Studios Hollywood based on the Fast and the Furious movie franchise. "It's the next generation of entertainment," David says. "I've been in the media space and the entertainment space since I left film school, which was in '92, and I've never ever seen anything attract A-list talent the way this does. We've had Al Pacino banging on the door twice in a week to see the technology. We contacted Alicia Keys and said we're doing Ray Charles [resurrected as a hologram]. It was, 'I have to be in it.'" (Keys, who previously appeared with a Sinatra hologram, declined through management to discuss the event. Pacino did not respond to a request for comment.)

Others are finding more potentially meaningful ways to use the technology. A group protesting new laws curbing freedom of speech in Spain faced steep fines for gathering in front of the Parliament—so they took to the streets as holograms. Videos of the ghostly sign-waving crowd torpedoed around the Internet.

In Austin, Texas, Zebra won a bid from DARPA, the military's research-and-development wing, to create the Urban Photonic Sandtable Display, a full-color holographic image that can rotate in space. The company has discussed providing holographic maps of desert regions along the U.S. border in Texas and Arizona to Customs and Border Protection agents, Doane says. The Federal Emergency Management Agency might eventually use the maps for disaster response.

2016

and

Beyond

Could Narendra Modi's idea be repeated here, so that a presidential candidate might stump as a hologram in New Hampshire while shaking hands in person in Iowa? Maass says a team from Hillary Clinton's campaign visited David's Beverly Hills studio last year and seemed intrigued. "I'm pretty sure she's going to go for it," Maass says. "If Hillary does it and she wins, then it's going to be very easy to have it be seen as a tool." (The Clinton campaign did not respond to a request for comment.)

Maass says he's spoken with national political leaders on several continents. "The use of it in politics is phenomenal," David says. "Whoever embraces it for 2016 will win. We are kingmakers here."

The campaigns are, predictably, more circumspect. Tim Miller, communications director for Jeb Bush, says he has no hologram plans yet but adds: "We are committed as an organization to leveraging technology, so you never know."

Scott Goodstein, founder and CEO of Revolution Messaging, was the exter-

nal online director for President Obama during his 2008 campaign, so he knows something about squeezing votes out of technology-based tools. He says that based on what happened in India, presidential campaigns might look at the hologram technology—but the high-tech illusion won't be enough to make much difference on its own. "Will holograms get people to pay more attention to a candidate's message?" Goodstein says. "That to me is the big question."

Regardless, Maass and David will keep looking for new venues for their hologram experience. Founders of the National Comedy Center, set to open in August 2016 in Jamestown, New York, Lucille Ball's hometown, didn't want a museum or hall of fame. They wanted a place where people could experience comedy—where the world's greatest comedians could come

movie trope in which a character alters a holographic image hovering in the air with the swipe of a finger. Zebra is working on versions in which someone sitting at a computer could draw a graphic on or otherwise manipulate a 4 x 6-foot hologram projected onto a wall.

Zebra suddenly has a growing roster of competitors—particularly in the realm of medical imaging. Holography is capable of showing patient organs and bones with greater precision and accuracy than conventional two-dimensional imaging tools like ultrasound—and it could also help doctors pinpoint issues in intricate, multifaceted organs. A California startup named EchoPixel created a software platform, True 3D Viewer, for use in diagnostics and surgical prep. RealView Imaging generates real-time holograms that can be updated digitally



to life, even the dead ones. Chairman Tom Benson says he discovered Hologram USA's website. "I thought, I hope it's as good in person as it looks online," he says. "When I saw it and realized what it could mean to us, a lightbulb went off."

The NCC will feature as its cornerstone attraction a virtual comedy club where visitors can watch holograms of iconic comedians like George Carlin and Rodney Dangerfield perform classic sketches. "It will be an area where people can suspend their disbelief," Benson says, "and experience routines as if they were there."

A Ronald Reagan hologram in his presidential library? That one is in development, Nussbaum says. (The library did not respond to a request for comment.)

Zebra Imaging is working on what Doane calls "real-time collaborative holographic visualization," but what might simply be called holograms you can play with. Picture the old science-fiction-

via a stylus. If the Food and Drug Administration approves it, the device could allow surgeons to generate a hologram of a patient's heart to help them visualize how best to proceed with an operation. Nanolive's 3D Cell Explorer generates stereoscopic images of tissue at the cellular level—a technology that may help researchers better grasp how diseases interact with the body.

Some of the ideas flying around make you feel both the wonder and the consternation that Luis Chiappe felt in the presence of that dinosaur. The technology might be limited only to whatever the imagination can come up with—including extending, in an ephemeral way, our own lives. Nussbaum recently worked with a wealthy industrialist in his nineties to create a hologram that would allow the man to give his own eulogy. But before they could make it happen, the man died, and the eulogizing was left to humans. PM



CERTIFIED!

Popular
Mechanics

HOW TO

BUY A CAR

THE DEFINITIVE GUIDE

VOLUME #

192



ISSUE #

07

PHOTOGRAPHS BY JAKE STANGEL

ABOVE ALL ELSE, REMEMBER: This should be fun. You're buying a wonderful thing—a thing that will bring you and your family joy (interspersed with occasional consternation but, hopefully, mostly joy), safe passage, and a comfortable ride on those days you just feel like driving. At base, the car is a possession, sure. A means to accommodate a fundamental need. But it can also be an opportunity to express who you are. And to show up your neighbor.

NEW! THE DOS AND DON'TS OF BUYING A CAR: **DO** buy the warranty on a used car. **DON'T** let them apply rebates until after you have a final



price. **DO** dress down. Studies show that high-end retailers assume casually dressed patrons can spend more, so they give you better service.

THE TEST DRIVE

BY EZRA DYER

Over the past fifteen years I've driven more than a thousand cars. Along the way I learned what matters—and what doesn't—when you're sizing up a new ride.

Wait for Bad Weather

A blustery, rainy day will tell you more about a car than you'll learn on a 75-degree summer afternoon. Is the highest windshield-wiper setting fast enough for you? Can the car get off the line at a stoplight without triggering the traction control? With the decreased grip, you might also learn a thing or two about the chassis, like whether it's tail-happy, or if a midcorner bump wants to bounce you into the ditch.

Lose the Salesperson

If you can, take the drive without the salesperson. How knowledgeable he is beside

the point—he's distracting you. The first five minutes is when you'll get the strongest impressions, when oddities jump out at you. That's not the time to be nodding and saying, "Yeah, uh-huh, the car is a Wi-Fi hot spot? Nifty."

Know What You Want

What annoyed you about your last car? Does the new one solve those problems? If, say, your old car didn't have seat heaters and you decided your next car had to have them, don't even test drive a car that doesn't fill the bill. Test drives have a way of turning into purchases.

Play With the Controls

Pay attention to the interfaces—stereo, climate, navigation. A laggy touchscreen or confusing layout can sour you on a car more quickly than you think.

Push the Engine

Get out on a highway, somewhere you can merge and run hard through the first couple of gears. If the engine's turbocharged, is there much lag between the time you step on the accelerator and when the turbo delivers its boost? If a car has a high redline, do you actually need to rev it that high to reach the power—that is, will it feel gutless unless you drive everywhere at 7,000 rpm? Does the engine sound smooth or coarse? Coarse can equate to sporty, but smooth might be what you want to live with.

Pay Attention to the Chassis

When you hit some railroad tracks, does it sound like you're driving inside a bongo drum? The less the structure moves and rattles, the better the suspension system, and the better

the ride will be over the life of the car. If a new car feels junky on these early bumps, it's going to be ten times worse by the time it's got 50,000 miles on it.

Consider the Shifter

Do you like it? Even on an automatic, there are all sorts of shifter layouts—knobs, levers, push-button systems, mechanical, and fully electronic. It might sound silly, but some people like a shifter with tactile feedback—not buttons, not an electronic stalk—so take that into consideration.

Check the Camera

If the car comes with a backup camera, test it. How's the resolution? Some produce video that looks like a feed from a submarine exploring the Mariana Trench. And how long does it take to boot up? I've tried cameras so slow that I'm out the end of my driveway before it gets around to sending an image to the dash. Since you quickly come to rely on a backup camera, a bad one is worse than none at all. And a lot more expensive.



THE DECODER

A handy guide to terms you may encounter in car listings.

Runs like new: No discernible problems
Needs TLC: Needs at least \$1,500 of work
Runs good: Runs well
\$2,000.00: \$2,000
Trade only: Some

components acquired through illicit means
Newer tires: Tires are at least 3 years old
Call or text: Text
Small crack: Medium crack

Medium crack: Large crack
Reliable: Ugly
Needed soon: Needed six months ago
Negotiable: Offer me \$500 less

OBO: Offer me \$500
Easy fix: Symptomatic of a larger problem
Mechanic special: Might run eventually
Needs minor bodywork: Needs bodywork

Great for the price: Not great
Check Engine light is on: I didn't treat this car very well
Roomy: I have lived in this car at some point

DON'T wear your dirty gym clothes. There are limits. **DO** ask them to throw in the upholstery protection. **DON'T** ever pay for it, since it's basi-

QUIZ

WILL YOU BE GETTING A GOOD DEAL ON YOUR CAR?

A helpful quiz. Add up the points to determine your score.

1. Want some coffee?

- a. Sure. (0)
- b. No thanks. (0)

2. We have doughnuts too.

- a. Sure. (0)
- b. Nice try! (2)

3. If you're buying a new car, have you already looked up the invoice price of the car you want online?

- a. Yes. (5)
- b. No. (-5)
- c. What's an invoice price? (-10)

4. The price the dealer paid the manufacturer.

- a. I knew that. (2)
- b. Oh. (0)

5. How's your credit score?

- a. Over 700. (15)
- b. 600-699. (10)
- c. 500-599. (3)
- d. Under 500. (-5)

6. Are you planning on financing?

- a. Yes. (5)
- b. No. (5)

7. How are you at math?

- a. Good. (5)
- b. Not bad. (0)
- c. Completely clueless. (-5)

8. Do you have a trade-in?

- a. I don't discuss that with anyone until after I've settled on a price. (10)

- b. Yep. (0)
- c. No. (0)

9. How many times are you willing to threaten to leave the dealership?

- a. Zero. (-2)
- b. One. (0)
- c. As many as it takes. (2)
- d. I don't threaten. I leave. (10)

10. You're standing in line at the grocery store. Which of the following would you buy on impulse? (Mark all that apply.)

- a. Gum. (-1)
- b. Candy bar. (-1)
- c. The *Enquirer*. (-1)
- d. The milk someone else left behind. (-2)
- e. Anything the cashier promises is good. (-10)

11. Picture yourself at the dealership after buying your car. Is the salesman smiling?

- a. Yes. (0)
- b. No. (10)

12. Are you smiling?

- a. Yes. (10)
- b. No. (-10)

ANSWER KEY

► More than 50:

You will be getting a good deal.

► 0-50:

You will get a good deal, as long as you find an honest salesman.

► Less than 0:

You should really bring a friend.



THE \$2,000 RULE

Why I'll never spend more than two grand on an old car.

BY EDDIE ALTERMAN, editor in chief, *Car and Driver*

OH, I'VE HAD expensive old cars before. Collectible stuff, like a 1959 Porsche 356 Convertible D. The one with the Speedster body and the roll-up windows. I remember the moment it first betrayed me.

In the summer of 2000 I was on a weekend drive when the throttle pedal went limp. I looked under the car and saw a brace-let of broken metal. The Porsche—a simple thing, really, nothing more than a Volkswagen Beetle—has a seventeen-piece throttle linkage serviceable only by Nobel laureates in physics.

Having an expensive car is like having a big pile of money in your garage. Every night fairies come in and steal a little bit of it, and you're powerless to stop them. You just have to wait it out and hope that the car eventually appreciates in value.

I made a decision that

summer day: I would never buy an old car that cost more than \$2,000. That way, I would never really have to worry about it. I could learn how to work on it without destroying its value. Though it might be cheap and mold-ridden, it would still do what we want all old cars to do, which is to transport us back in time. My 1983 Mercedes-Benz 300D sedan (below) is the best horrible car I've ever owned. It's a loyal old dog, and just as slow. It cost me exactly \$2,000.

The Porsche? I remember the final time it betrayed me, because it was only the other week. I bought the car for \$25,000 in 1999. I sold it three years later for \$25,000. Recently I was looking through an issue of *Sports Car Market* and there was a red 356 just like mine. It had just sold at auction for \$187,000. That kind of bullshit would've never happened with a \$2,000 car.



cally just Scotchgard. **DO** bring a magnet. Anywhere it doesn't stick means you're dealing with Bondo body filler. **DON'T** worry if anyone sees



CONFESSIONS OF A DEALER

Buying a car requires trust. Trust requires honesty. And to get honesty, well, sometimes you need anonymity. We spoke with a veteran salesman in the Midwest, who shared some of the wisdom—and a few tricks—he's picked up.

It's not like it was in the eighties. Car manufacturers can't get away with building a sub-par product.

Don't go car shopping without already having a price.

Ninety percent of people who come in say that they're just looking. I'm the same way. I like to be left alone when I shop for a car. I'm looking for certain things, like bolts that have been cranked on. If there is a wrench mark on a bolt, I know that the fender has been replaced.

The salesman gets paid off the amount he gets over invoice,

which is the price the dealership paid to get the car from the manufacturer. (Invoice does not include holdback, the money given to a dealership after the car sells.) If someone pays less than the invoice, the salesman gets a mini deal—a flat payout from the dealership, usually between \$100 and \$200. Most cars sold today are mini deals. Especially new cars.

If you really want to know what vehicle to buy, ask the service department. They see what's coming into the shop. They know what's having trouble.

My No. 1 job is to get people

to finance the car through the dealership. Which means cash is the worst thing to tell me you want to pay with. You're basically saying that I'm not going to make a dime off you. If that's the case, you want to give as little information as possible until we've agreed on a price.

A lot of times we add \$1,000 to the price and take it away later, assuming that everyone will negotiate. And everyone will negotiate. Even the sweetest old ladies in the world turn into saber-tooth tigers when they sit down at the desk.

The worst thing you can do is walk in with your guns blazing, insisting on a price that you know is too low. You'll be sent out the door. We just won't go out of our way. If a nice customer asks, "Do you have any of these?" typically I would offer to dealer-locate a car. For a jerk it's just "Nope."

Be realistic. Don't come in trying to get a \$35,000 car for \$200 a month. Customers are still looking for that \$200 payment. That's what I was looking for in 1989. The reasonable payment is \$300, \$400, or \$500 a month. If you're realis-

“ We say that you'll only get a price that day. But we're salesmen. We want to sell cars. If you come back looking for the same deal the next day, you're going to get it.”

tic, you can spend invoice only, and that's before rebates.

Used-car values are so tough. Kelley Blue Book always hits it high. Edmunds too. Higher than what you can buy them for in an auction. We can't give you \$15,000 because we are going to try to sell it for \$16,000, and every car we bring in is going to need \$500 to \$1,000 worth of work. Then the next guy is going to want to negotiate.

When you're taking your car in to trade it in, for the love of God, clean it. Four out of every five cars I take in on trade are filthy. Not just dirt on the outside. There's trash, stuff in the glove box, cigarettes in the ashtray, garbage on the floors, kids' trash everywhere, food. And then they argue about how much the car is worth. That's one place you can affect your trade-in value: Clean your car.

TIP!

“The best shopping months are August and September. That's when dealers start to slash prices on outgoing-model-year vehicles to make room for next year's models, and shoppers still have a healthy selection of inventory to consider.” — AVI STEINLAUF, CEO, EDMUNDS.COM

you using it. **DO** feel the edges of the hood or quarter-panels for paint seams (a common sign of repair work). **DON'T** taste for salt damage.



Over the past few years I've used four different online services to buy a car. Here's how it went. — E. D.

eBay Motors

I bought my 1998 BMW M3 convertible on eBay. Lesson learned: Make sure it's such a good deal that you're okay with any foibles undisclosed by the seller. So how do you know you're getting a nice price? Do an advanced search and look at the completed listings. You'll see what sold. Maybe even more important, you'll see what didn't.

TrueCar

TrueCar is a great tool for removing the mystery of the MSRP. Say you want a 2015 Chevrolet Silverado 1500. For that truck, TrueCar has more than 10,000 actual transaction prices that help you see what you should pay (probably \$2,000 under invoice). Be forewarned that if you do sign in and search a particular model, dealers will begin calling you within about three minutes.

AutoTempest

This is an aggregator that covers a number of the popular car-buying sites. The key feature, though, is Craigslist aggregation. I used it to locate and buy a truck that ended up being 800 miles away. And manually searching an 800-mile Craigslist radius is a little masochistic even for hardcore used-car junkies.

Cars.com

Cars.com is useful simply because it's so huge that it quickly exposes outlier prices—both high and low—thanks to the national sample size. It's also great for finding leftovers, since you can search new cars and then sort by oldest first. Did you miss out on the Pontiac Solstice GXP back in 2009? Not to worry, Malouf Buick GMC in New Jersey still has a new one. Although they're evidently not in much of a rush to sell it.

A FEW OTHER OPTIONS

► CARVANA

360-degree views reveal features and flaws. Most cars are delivered the next day, with a seven-day test drive. If you live in Atlanta, pick up your car at the eerie but fantastic car vending machine.

► CARLYPSO

If you're selling, Carlypso comes to your house, inspects your car, and installs a device that lets potential buyers take (authorized) test drives. Available only in California.

► BEEPI

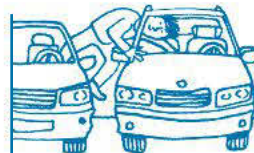
If your car passes a 185-point inspection provided by Beepi, it will list and sell it within thirty days or buy the car from you. Buyers get a ten-day money-back guarantee.

THE SUGGESTION

Test-Drive Every Car on the Same Day

The sad truth about modern cars is that, at least within their respective segments, they are often remarkably similar. Most have comparable powertrains, handling, cabins, and technology. That's why it's vital to drive as many prospective vehicles as possible within a short period of time. Suddenly all of the minutiae you didn't notice pop out at you like a Magic Eye poster. That cup-holder placement on the last car now borders on egregious, and what's with the dead steering on this one?

Unless you happen to be shopping a dealer row, where your options are conveniently laid out next to one another, the biggest



challenge will be logistics. Luckily, most dealers are open to the solo test drive. Tell one you want to show the car to your family or (if it's a used car) take it to your mechanic. Then drive it to the other dealership and test drive the next car. This method works best when you're down to two choices, but if you can't do that, take your own car and avoid dillydallying. The less time between drives, the better the decision you'll make.

—ANDREW DEL-COLLE

THE USED-CAR QUESTIONNAIRE

☒	• Can I take a look at the title?
☐	• Why are you selling?
☐	• Are you the original owner?
☐	• If not, do you know anything about the previous owner?
☐	• Did you keep a service history?
☐	• Was this your primary car?
☐	• How long have you owned this car?
☐	• Did you ever live anywhere else with this car?
☐	• Were there ever water issues in the interior?
☐	• Why is the mileage so low? (Best if asked only when the mileage is low.)
☐	• Do you mind waiting over there while I run through the 101 checklist items on my Popular Mechanics used-car app?

A FEW THINGS TO ASK BEFORE YOU BUY A CAR FROM A REGULAR PERSON.



Did you know Popular Mechanics has an app to help you buy a used car? It's free! And it will run you through 101 important questions to ask yourself or the guy selling you a car to ensure that you don't go home with an expensive headache.

DO get preapproved for a bank loan before going. **DON'T** assume the bank's rate will be better than the dealership's. **DO** pay attention to the

THE USED-CAR

HALL OF FAME

Picking one of the greatest, most classic, and possibly most underappreciated used cars is easy. You just have to know who you are. — E. D.



YOU ARE: A family man. You enjoy nature, but would just as soon drive up a mountain as hike it.

YOUR CAR: 2005–2008 Subaru Legacy GT
TYPICAL PRICE: \$9,000

This might've been the car that triggered the dawning public awareness of Subaru's virtues. This Legacy paired all-wheel drive and a 250-horsepower turbocharged four-cylinder with sharp styling and manual or automatic transmission. Sound like a bargain Audi S4? That's pretty much what it is.



YOU ARE: A fan of trips without planned destinations.

YOUR CAR: 1993–1997 Toyota FJ80 Land Cruiser
TYPICAL PRICE: \$5,000



YOU ARE: Looking for a luxury crossover at a discount.

YOUR CAR: 2010 Lincoln MKT EcoBoost
TYPICAL PRICE: \$25,000



YOU ARE: Practical, with a lot of things to haul around.

YOUR CAR: 1997 Ford F250 Power Stroke
TYPICAL PRICE: \$6,000



YOU ARE: Interested in a sporty car but not a sports car.

YOUR CAR: 1998–2000 Ford Contour SVT
TYPICAL PRICE: \$3,000

In terms of reliability, it's hard to beat a mid-nineties Ford truck with the Power Stroke diesel. The 7.3-liter Navistar V-8 was used in International buses and doesn't break much of a sweat in a pickup. These engines are known to go 500,000 miles, so if you find one with 150,000 miles on the odometer, it's just getting broken in.

Ford's Special Vehicle Team turned the basic Contour into a legitimate import-fighting front-wheel-drive sport sedan. With a manual transmission and 195 or 200 horsepower out of its high-revving V-6, the SVT far outmuscled the four-cylinder competition and sounded great doing it. An underrated performance bargain.



YOU ARE: Not yet retired. You deserve something fun.

YOUR CAR: 2001–2006 BMW E46 M3
TYPICAL PRICE: \$16,000



YOU ARE: Looking for an investment.

YOUR CAR: 1993–1997 Land Rover Defender 90 NAS
TYPICAL PRICE: \$50,000

Like all Land Cruisers, the 1993–1997 model was mega-expensive when it was new. But now they're cheap enough that you can use them for their intended purpose—serious off-roading—without feeling bad if you restyle a couple fenders out on the trail. Look for a seven-seat model with the optional triple locking differentials and you'll have a soon-to-be-classic luxury truck with room for the whole expedition party.

The MKT is a sneaky used-car buy for two reasons. First, Lincoln has a great certified preowned program that extends the bumper-to-bumper warranty to six years or 100,000 miles. Second, in twin-turbo EcoBoost guise it's actually fun to drive. Buy a certified preowned car and you can end up with a new-car warranty on a half-price machine. These are some of the rationalizations I made when I bought one.

The 2001–2006 BMW M3 had lively steering, a high-revving straight-six, and a hunkered-down suspension with big fat tires under the fenders. It looked ever so mean. I remember an editor at the time complaining that the M3 was such a great car, it was actually hard to write about. "It's excellent," he said. "What else are you going to say?" Newer models are more powerful, but this one remains a high point in overall sport coupe greatness.

Land Rover imported fewer than 7,000 NAS (North American Spec) Defenders between 1993 and 1997, and they haven't offered the model in the U.S. since. The combination of rarity and effortless cool has led to a climb in Defender prices, meaning that this is a car you might drive for a few years and then sell at a profit. Or just keep it and enjoy looking like an outdoorsy Bond villain every time you drive to the beach.

TIP!

"One reason to buy a used car is that the car has been out awhile. That means you have a lot of safety and reliability information to consider. Has this car had to be serviced a lot, traditionally? Is it a safe car? Those years in the market will help you make a better decision." — CLIFF WOOD, EVP, CARMAX.COM



CHIN, A FRIEND OF A FRIEND of my father's, with a nickname whose origin was obvious when you looked at him, sold cars in Florida. His stories of auction deals had made their way to Pittsburgh, where they'd inspired in me dreams of driving something other than an inherited '83 Camry. And so, with my paperboy savings fully liquidated, my dad and I flew to Orlando and found ourselves walking aisles of cars in what looked to be a barnyard parking lot.

We saw the crowd first. The car was running, hood up, and when we walked over Chin plucked the throttle on the carburetor. The car roared and shook. When the attendant drove it into the barn a few minutes later, chirping the tires



as he failed to hold it down, we followed. The car was listed as a '79 Z/28. That was all we knew—no trip to a mechanic, not even a minute in the driver's seat, let alone a test drive—and that was enough. Chin translated the confusion, bidding and telling me the price as it went up in smaller and smaller increments. But I didn't want to reassess what the car was worth to me every time he checked in. I wanted the car. I said as much to Chin, and after a few more wags of a finger or drops of that monster chin to his chest, the car was mine.

There was no sitting in a salesman's office. No haggling over floor mats or payments. There was no time for anything but excitement. Turned out I was the new owner of a ten-mile-per-gallon, 400-horsepower beast with a broken speedometer and a racing clutch that took all my strength to get to the floor. We drove the thousand miles back using the tachometer and the flow of traffic to gauge our speed. And sure, blue smoke started somewhere in North Carolina, but we somehow found a Kmart with a service bay open on Sunday, and a guy willing to replace the oil-sending unit even though he had already clocked out.

We made it home without any more trouble, and I immediately got to doing all of the things you should do with a car you don't understand. I taught myself to rerun a speedo cable, fixed an off-track window, blew a fuse every week as I tried to fix an aftermarket electric gas pump, and put more of my high school identity into an object than I probably should have. Twenty years later, I don't have the car, but I do have a story. Those don't usually come from the dealership. —PETER MARTIN



INFOTAINMENT SYSTEMS

Most carmakers now offer competitive dash technology—smartphone integration, touchscreens, apps, voice command. The real difference is how it's employed.

System	PRO	CON
Mazda Connect	One of the few nonluxury car companies to use head-up display and an intuitive scroll wheel for screen control.	The number of submenus is annoying (and distracting). Real-time traffic updates are oddly separate from the navigation app.
Chevrolet MyLink	Pair your iPhone and you can use Siri through the voice-command system, which is nearly seamless.	Instead of Bluetooth, iPhone owners have to use a USB cable to connect.
Ford/Lincoln Sync 3	The touchscreen is responsive and mimics a smartphone, so you can swipe, scroll, and zoom.	A lot of that touch-screen functionality isn't exactly useful. And it's not very pretty.
Chrysler/Dodge Uconnect	Large buttons are good for fat-fingered drivers. Wireless charging for properly equipped phones.	Features like heated seat controls (and volume?!) aren't given proper physical buttons.
Toyota Entune	Excellent integration of voice control into apps. Reads your text messages to you.	The screen on base models is pretty small, making it cramped and hard to use.
Hyundai Blue Link	Works with Android Wear to let you start the car or unlock your doors with a smart watch.	Unintuitive, with a touchscreen that often requires multiple taps before recognizing commands.
Audi MMI	Has a hard Back button so you don't have to scour the screen every time you open the wrong app.	No dedicated button on the steering wheel to end a phone call.
Mercedes-Benz COMAND	Very user-friendly, with a scroll wheel and real buttons.	Slow connection speed for cloud-based applications. Display looks a little like an iPad glued to the dashboard.
Honda HondaLink Next Generation	In the event of an accident, HondaLink Assist will automatically connect you with an operator if your phone is paired via Bluetooth.	The dual screens can be confusing. The GPS often takes a while to lock onto your location.

length of the loan (salesmen might extend the loan to lower your payments). **DON'T** forget that this is fun. At least it will be when you drive off the lot.





LEARNING

TO FLY

3 OF 4

THE LANDING

**MANY PILOTS WILL TELL YOU
LANDING IS THE HARDEST PART.**

IT IS.

BY

**JOSHUA
FERRIS**

PHOTOGRAPHS BY

DANIEL SHEA

POPULAR
MECHANICS

JULY/AUGUST
2015

77

• BY • THEN I WAS ABLE TO KEEP THE PLANE STEADY

as we raced down the centerline. I was able to climb out in a coordinated and measured way, searching the sky for traffic, until I hit our cruising altitude. By then I could arrest our climb with forward pressure on the yoke—a modest achievement as piloting goes, but one that really pleased me. A climbing plane wants to keep climbing, you see, and a hard nudge on the stick implies a willful hand and a made-up mind. I acted with authority and know-how to keep the plane in line, and on that day I remember feeling that at last I had command over the single-prop Piper Cherokee we called Six-Two Romeo.

By then I also knew how to keep our altitude steady, and how to let turbulence wash over the airplane without micro-managing the stick. And I knew how to pull the engine back from the red line when it started running hot. I knew how to lean (or thin out) the mixture upon reaching our cruising altitude and all the rest of the cruise checklist. I knew how to spot Greenwood Lake from 2,500 feet, that blue slit of water with its lonely eye of land. I knew how to do clearing turns over the practice area before I began my maneuvers, and I knew how to do my maneuvers.

My maneuvers were not perfect, and my navigation was not perfect, and my communication with air traffic control was not perfect. I might not say this or that correctly, and I could flub the protocol with the best of them. But by then I knew that, however formal and stern air traffic controllers might seem, they allowed for honest mistakes.

And by then I knew a bit more about the man next to me. Tom Fischer and I had been inside the tight confines of Six-Two Romeo for many hours together, on long days of blinding heat and short afternoons of freezing cold, and though I had tried to end his life in any number of interesting ways, he never took it personally. Nothing I did in the air rattled him. He was like the man who enters a snake pit or lion's den and has a calming effect on all the savagery.

Tom kept his hands near the controls, especially during critical moments, but by then, he was just as likely to go quiet and stare out the window for traffic while I did what was necessary to pilot the plane. Those long stretches of silence as we cruised over the pine forests of New Jersey were very companionable. There was the rock quarry that looked at once like a pulled tooth and an entire mouth of molars, and there were the swimming pools and tennis courts of the rich, and there was the heavy swath of power lines like a scar upon the earth. These casual moments gave me a foretaste of the silence that would attend my first solo flight—the prospect of which, in idle moments, terrified me. But if it was like this, I thought, there was no reason to be scared. My confidence grew every time Tom went silent.

ONE DAY IN October, we came in from the practice area north of Greenwood Lake and reported our approach to Caldwell Tower. I had been taking flying lessons for about ten weeks. A half-mile out, we joined the pattern on the downwind. The downwind is the first of three legs that finally puts you on the runway. Abeam the numbers, I reduced power and began to descend.

At 900 feet, I made my base turn into a modest tailwind. The view outside the windscreen was of a broad hillside blanketed by trees and toothpicked by signal towers and power lines. The runway was off to my right. I pitched for the right airspeed and trimmed the yoke. At 700 feet and falling, I turned base to final.

As the wing dipped heading into that final turn, the windscreen filled with earth, trees, houses. Trees et al have the power to terrify during a descent, when you seem to be heading straight for them belly-first. But by then I could anticipate and manage that fear. What I was seeing was the naturally occurring phenomenon of a customary landing. However, it takes a lot not to nose up, out of instinct, to put a little distance between your ass and the earth. By then I was trained not to nose up—“don’t get pitchy,” Tom liked to warn. But bad habits are hard to break.

Runway 22 was ahead of me now, just past the highway. To my dismay, I discovered that I was way off the centerline. I’d allowed myself to be blown off-course by the tailwind. I needed to crab over. Meanwhile I was falling more than a thousand feet per minute, and something was off. We were sinking.

We were sinking over I-80 and the Wayne Town Center shopping mall. The pines below me were whipping past like green skewers of death. The rooftops were rearing up, gaining compactness and detail.

“We’re sinking, Tom.”

“You got pitchy,” he said. “And now your airspeed is off.”

I had done my best not to nose up at the sight of all those fast-approaching trees, but the facts were the facts. If we were sinking, I had nosed up.

“Add power now,” Tom said.

- Joshua Ferris is the author of three novels, including *Then We Came to the End*, a finalist for the National Book Award, and *To Rise Again at a Decent Hour*, nominated for the prestigious Man Booker Prize in the first year American writers were eligible to receive it. Look for the final installment of “Learning to Fly” in our next issue.

I heard the urgency in his voice. I reached for the throttle.

In Six-Two Romeo, the throttle works two ways: by pressing it in and out, like a foosball handle, for greater thrust; and by twisting the knob, which yields a more refined dose. At that moment I needed to really punch it, but for some reason, I just gave a pansy little twist. What's worse, I went the wrong way. We began to sink even faster.

"When I say add power, I don't mean little twists. I mean *add power*."

I punched in the power. It restored our lift and we climbed away from the trees and the rooftops. But we still had to land.

"Should I go around?"

"Going around is always an option," he said.

This was one of Tom's refrains. He liked to tell the cautionary tale of a pilot who crashed at Caldwell trying to land when she should have gone around. "Having to go around is never the embarrassment," he said to me more than once. "The embarrassment is needing to go around and choosing not to."

"I think I'll still try for the runway," I said.

"Okay," he said. "Then you'd better start taking out some power."

Add power, take out power. Speed up, slow down. Climb, descend. Landing is a dance. Its orchestrations are challeng-



ing, intense, and variable. If you're doing something wrong, odds are it began seven moves back. How to fix it? Dance faster, better, mightier. Or go around.

We floated over the highway, still being pushed to the left by the tailwind. Now, because of the added power, we were too high. Tom told me to take out all the power. We started to sink again. He warned me to keep the nose down, but not to aim for the runway. Another refrain: "You can't force an airplane to land." I thought once more about going around. Dismissed that thought. And then—

Everything happened at once: We came down over the runway. I pulled way back on the yoke. We lurched to the right. The runway disappeared. I mean *disappeared*. I was inches from concrete going ninety miles an hour, starting up into a windscreen full of sky. How to correct? I had no idea. The controls in my hand might just as well have belonged to a video game flashing INSERT COIN NOW. I stopped piloting and braced for impact.

Seconds later, Tom was calmly taxiing the two of us down runway 22.

TOM WAS CONSTANTLY saving me from horrific landings. Over and over something went wrong. It was never the same thing twice. I came in too high. I came in too fast. I shied away from the tarmac. I lunged at the tarmac. I loved to get down really close and then roll

the plane to the right at the last second for no reason at all, and then wobble over the runway like a fledgling bird. I came in crabbed when I should have been straight, and I came in straight when I should have been crabbed. I aimed for the runway as if the plane were a dart and the runway a bull's-eye, a sensible way to land only for wheel manufacturers and slow news cycles. When not aiming like a dart, I loved to pull up on the yoke too aggressively. That sent us back into a takeoff attitude right when we were trying to land and had no power to climb, and we flirted with a stall fifty feet in the air. No matter what the mistake was, things usually got so muddled and dire in the final seconds that I abandoned the controls out of sheer helplessness and prayed to Tom, the patron saint of hapless pilots.

To land well is to contend with paradox. You need patience when things are most hurried, composure when things are most fraught. You need focus when your attention is most scattered. You need to make small adjustments when only big ones seem appropriate. You need a light touch on the controls when the urge to yank and grip and pull them off the panel is at its strongest.

The first time I turned my attention entirely to Tom and watched him land Six-Two Romeo, I was moved to laughter by the complexity of it all. He was descending, turning the yoke, applying back pressure, lowering the flaps, adjusting the trim, peddling the rudder, adding power, nosing down—all more or less simultaneously. How many limbs the man had! How harmoniously they moved! I was put in mind of prodigies and athletes, of the grace that remains hidden until you see a man at his calling. He was passing cool as a cucumber over I-80. He was descending to the numbers on the runway. He was riding the flare like a man in a chute. When he finally kissed the rear wheels to the runway, the tarmac was as soft as a mattress of silk.



A

FTER THAT botched landing, I went home and reviewed landings in books and online. I watched YouTube videos of small planes coming into Caldwell.

The next time Tom and I went up, I didn't do any better. I also seemed to forget how to turn. I had coordinated turns down cold several lessons earlier. So why was every turn around the pattern now 45 degrees, as if I were trying to avoid enemy fire? I had a setback. A collapse. Call it what you want, I was back at square one—while also trying to land.

"Forty-five-degree turns are kind of fun," Tom said after we had returned to Fischer Aviation. "Just not in the pattern."

"Where did my brain go? Where did my feel go?"

"You were dismissing the throttle again, I don't know why. And we have to break you of pinching the yoke."

"I'm making errors because I'm pinching the yoke?"

"Yes," he said, shifting into a whisper for emphasis. "I don't make this stuff up."

"And then I get down there," I said to him about the actual landing, "and it's a complete mystery to me what I should be doing."

"Well," he said, "maybe we'll do a little sim stuff next time and we can really nail that part down. Because it shouldn't be that much of a mystery."

By then I knew that flying meant failing. I had failed at steep turns and I had failed at slow flight. I had failed to keep my altitude and I had failed to keep my heading. I'd had close calls and doh! moments, made mistakes of ignorance and mistakes of arrogance. Sooner or later, I got a handle on things. But there was something categorically different about the landing. You have to put all of the pieces together at once, with no time to spare, while staring into the dragon's mouth.

"I don't think I can solo," I said to my wife that night.

"Why not?"

"I don't want to die."

"I don't want you to die, either."

Why don't you quit?"

She hated flying and had been encouraging me to quit.

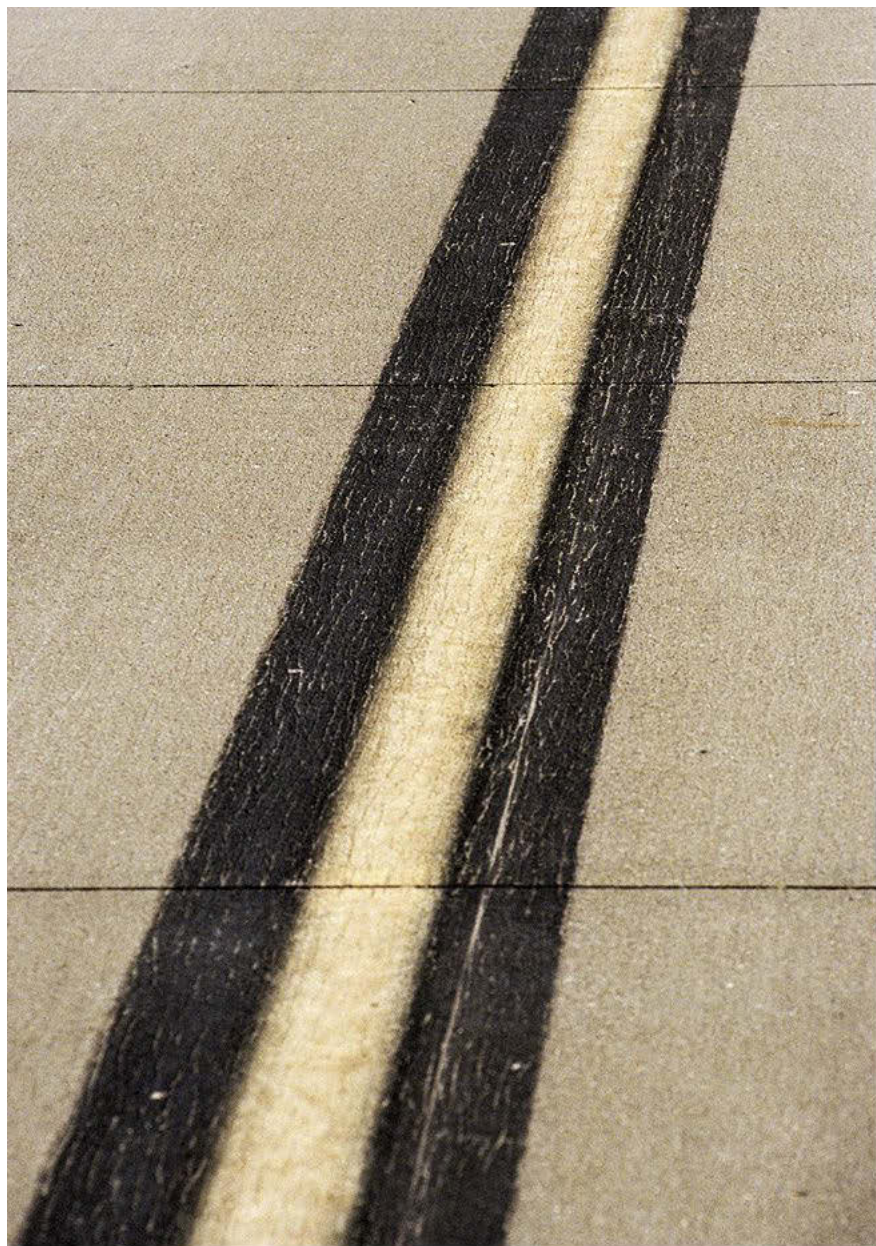
"I can't quit," I said.

"Why not?"

"Because I have to solo."

But the truth is, I wanted to quit. In the endeavor to do anything difficult, I inevitably quit a hundred different times, if only mentally. Something to vent the pressure for an hour or two, until the resolve returned. My resolve was a living thing, subject to changes in fortune. I had to tend to it, nurture it; sometimes that meant tricking it. If the temptation to quit wasn't ever-present, whatever I was doing probably wasn't that

EVERY ONE OF MY
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hard. One of the reasons I agreed to take flying lessons was the certainty that it would be hard. I'm a novelist; I take a perverse pleasure, obviously, in hard things. And because I knew it would be hard, I knew I would quit, at least mentally, a hundred different times.

To quit is to bow out before the achievement of a specific goal. My specific goal was to fly solo. That meant heaving Tom from the plane and heading up alone, which meant coming down alone, which meant landing alone. I could not comprehend how I ever expected myself to land without Tom beside me when almost without exception every one of my landings would have been very nasty, if not fatal, without his last-minute intervention. I knew how to take off just fine, I knew how to pilot around just fine. But landing? Oh, boy. There is an old-time humorous placard on the walls of Fischer Aviation that reads **FLYING LESSONS: 50 CENTS. LANDINGS: \$50.** That monetizes the obvious: It's the landing, stupid.

That night in October, I woke up reeling with night-

mares. No one in the world but me was awake, and my ears rang with the sound of the void. My heart was doing double time. I was filled with the darkest forebodings and doubts. The only sane thing to do was retire this unhealthy pursuit. Yes, I'd been long fascinated by flight. I'd stopped in awe since I was a boy to watch planes descend overhead. But what was I trying to prove? That I could master the physical world? That as I was turning 40 I was still capable of transformation? That I was never going to die? I had watched my father die a few months earlier. Learning to fly seemed the right antidote to that gradual and ghoulish decline. A surge of power, a new strength. But at two in the morning after terrible dreams, in the abandonment of the hour, I could no longer rationalize it. This is foolishness, I thought. This is childish. Go back to getting by.

Then the weekend came. It must have restored my faith. Monday was bright and breezy, blue for miles, without a wisp of cloud. I drove out to Fischer Aviation expecting a few



hours on the simulator. But something happened. Were we seduced by the beautiful day? By some strain of eternal hope? Without another word about the sim, Tom and I hopped into Six-Two Romeo.

Two hours later, we came out of the sky and taxied to the apron. We walked back to Fischer Aviation in silence. Tom filled out my logbook in silence. When he finally looked up at me, he said:

"Next time, we are doing the sim, rain or shine."

EARLY ON, TOM TRIED to teach me how to do steep turns. He began with a demonstration. At a centripetally lively 45 degrees, Tom's turn consisted of a full revolution from left to right while the world unfurled like a filmstrip outside the windshield. The impression was of being on a swift and steady merry-go-round. Then he handed the reins to me. On my merry-go-round, all the horses were drunk and easily spooked and occasionally had to take a knee.

We returned from time to time to the steep-turn maneuver. So many lessons went by. Then one day I went up and executed my first nearly flawless steep turn. I mean it had it all: an exact 45-degree bank, coordinated stick and rudder work, appropriate power adjustments, a continuous site picture, and the perfect maintenance of altitude and speed. I came down, not just someone capable of steep turns but a changed man. I was high with achievement and delight, relieved of every burden.

Landings weren't like that. One thing would click into place—say, the all-important approach. Then the leveling off would go haywire. Or the flare. Or a crosswind would complicate matters. Or I'd forget how to turn.

What I did that day to convince Tom that I needed some serious sim work was aim the nose of the airplane directly at the runway. This is one certain way to put you uppermost in the minds of the National Transportation Safety Board.

"You were a little better than ninety on the air-speed indicator and just getting faster and faster," Tom informed me.

I felt the heat of indictment spread over my body. You see, I hadn't known I was aiming for the runway. It came as a complete surprise. Sure, I could see it now. I felt myself pushing the yoke forward. I felt the plane speeding up. I saw the runway getting closer and closer as I prepared to plant the nose of the plane inside the meat of the tarmac. But at the time, I believed myself to be executing a safe and proper landing.

A reversal like my coordinated turns suddenly going wonky on me was something I could contend with. But this startling news of Tom's was something different. At any moment, I could do something dangerous that I should not be doing without even knowing I was doing it. That was the unknown sneaking out of the darkness, a glimpse of what crouched in wait beyond the dimensions of even the best preparation.

That was enough. I was quitting. No solo. My wife was very happy. My editor was understanding. I couldn't bear to tell my flight instructor. I showed up for one final lesson, mainly to drop the news. But we went flying instead. And that was the day I had my first perfect landing.



GREAT UNKNOWN

WHY ARE WE HERE?

WHERE DID WE COME FROM?

AND HOW MANY BATHROOMS ARE ON AIR FORCE ONE?

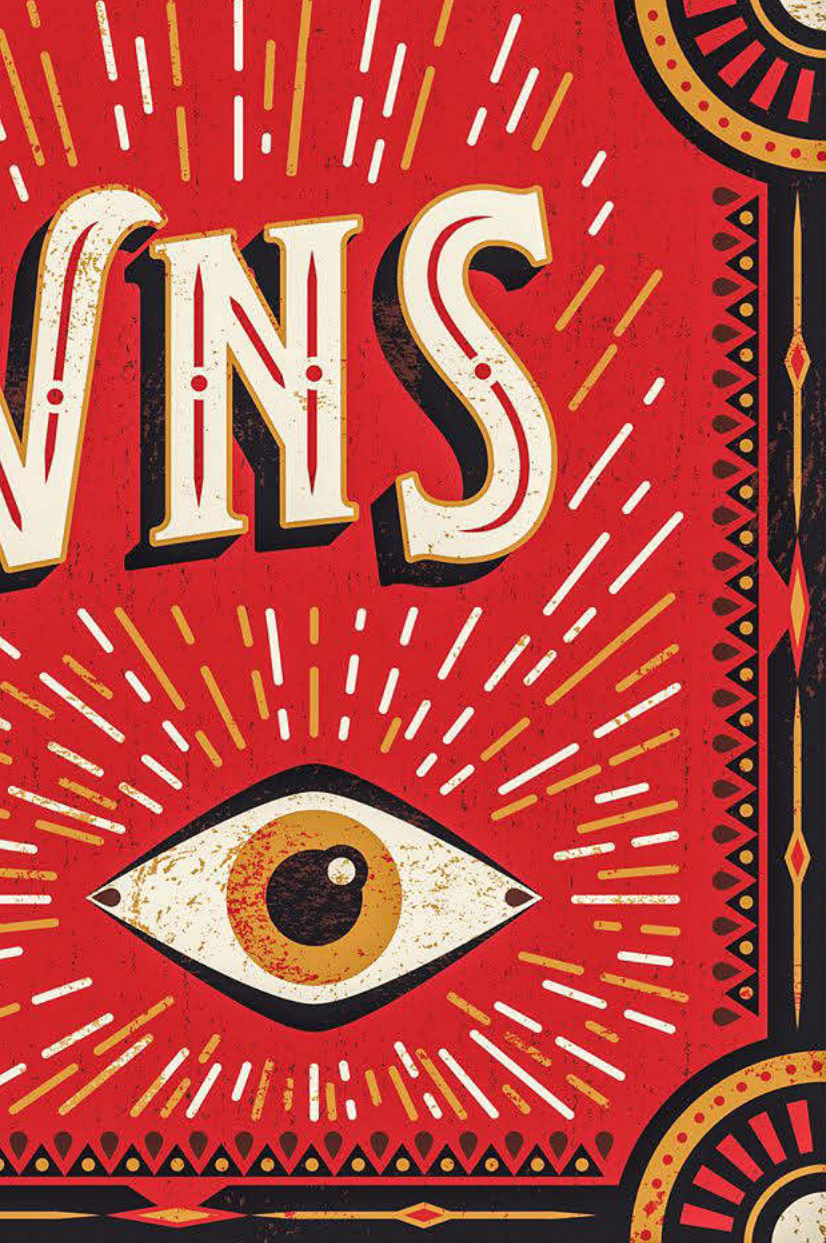
FOR THE FIRST TIME, HERE ARE ALL THE ANSWERS TO THE MOST CONFOUNDING AND UNGOOGLEABLE QUESTIONS IN THE UNIVERSE.



When was the first midair refueling of an aircraft, and whose idea was it?

AS FOR PRECISELY WHO came up with the idea for midair refueling, that's lost to history, but one suspects it might have been the first guy who ever crashed his airplane because he ran out of gas. The drive to actually develop the capability arose out of frustrations during World War I.

The first documented midair refueling occurred on June 27, 1923, when a DH-4B biplane flown out of Rockwell Field in San Diego by U.S. Army Air Service Lts. Virgil Hine and Frank W. Seifert successfully dispatched gasoline through a hose to another DH-4B, this one crewed by Lts. Lowell H. Smith and John P. Richter. Previous attempts at the feat, while creative, were more



Why do we bite the inside of our cheeks now and then? Isn't the human body a refined enough machine to not do that?

» The human body a refined machine? Please. We're talking about a contraption that sneezes, farts, belches, hiccups, itches, swells, shivers, bleeds, and, if certain disclaimers are to be believed, may arbitrarily incur "an erection lasting more than four hours." Doesn't sound too refined to us. In fact, it sounds like a mechanism eminently capable of injuring its occupant with random acts of intraoral aggression, which it is. Here's why:

First, you may have screwed-up teeth. Perhaps your mouth is too crowded, littered with extraneous wisdom teeth and the like. Maybe your teeth are just plain crooked. Or maybe you've got a bum set of dentures. Alternatively, you may suffer from a mental disorder (other than those you already know about). Cheek biting can be a feature of something called body-focused repetitive behavior disorder, a type of obsessive-compulsive behavior.

Most likely, though, the phenomenon is the result of an occasional glitch in our neural circuitry. Activities such as chewing, swallow-

ing, and breathing are hardwired into our brains—we don't need to acquire these abilities, we're born with them. There are times, however, when our mouths move in ways that are not the result of their factory defaults. Speech is a prime example. It can't be coded into our brains from birth, because we pick up one or more languages over time, requiring us to learn mouth movements in order to produce new sounds. Occasionally our mouth's hardwired instruction set and its learned behaviors will come into conflict. When they do, unfortunate things—such as biting our cheek, lip, or tongue—may result. These conscious/subconscious collisions might occur when we're talking and eating, or when we snack on something spicy that prompts us to move our tongue out of the line of fire. Indeed, research suggests that animals (who don't talk—no matter what Walt Disney would have you believe) almost never bite their tongues, lending further credence to your mother's admonishments to swallow before you speak.

stunts than practical methods for midair refueling. One naval aviator took a stab at it in 1921, dangling a grappling hook to snag a five-gallon gas can floating in the Potomac River. In another early attempt, a wing walker strapped a jerrican to his back and delivered the gas between planes "on foot."

We've come a long way since. Today military jets generally use one of two air-to-air refueling methods. There's the so-called hose-and-drogue, which is not, in fact, the name of an English pub (though it should be) but rather a refueling system in which an operator on board a tanker spools out a hose equipped with a mini parachute, into which the pilot of the refueling jet flies a probe mounted on the airplane. In the more efficient flying-boom method, the roles are essentially reversed, with the tanker's operator extending a rigid boom and maneuvering it into a receptacle on the gas-hungry jet. These fuel booms can deliver as much as 1,200 gallons a minute, which is more gas than most people burn in their car in a year.

{Q}
Whatever
happened
to Baby
Jessica?

{A}
She's
well.



Is it true that firing squads always load one rifle with a blank so that the executioners never know whether their gun has fired the killing shot?



► Yes, it's true, though one wonders whether it's necessary. Executions in Utah—the only state to employ firing squads in the past century—have typically attracted hundreds of volunteers for the five marksman slots needed. This does not create the impression of an especially conflicted populace. Even so, by tradition, officials load one of the five randomly distributed .30-caliber Winchester rifles with a beefed-up blank, meant to be indistinguishable in its recoil and other characteristics from a live round. The condemned prisoner is led into an observation chamber, strapped into a chair flanked by sandbags, and hooded. A doctor pins a patch over the prisoner's heart, to serve as a target. On cue, the marksmen, positioned twenty to twenty-five feet back, shoot simultaneously—each able to envision himself innocent by virtue of having fired the blank.

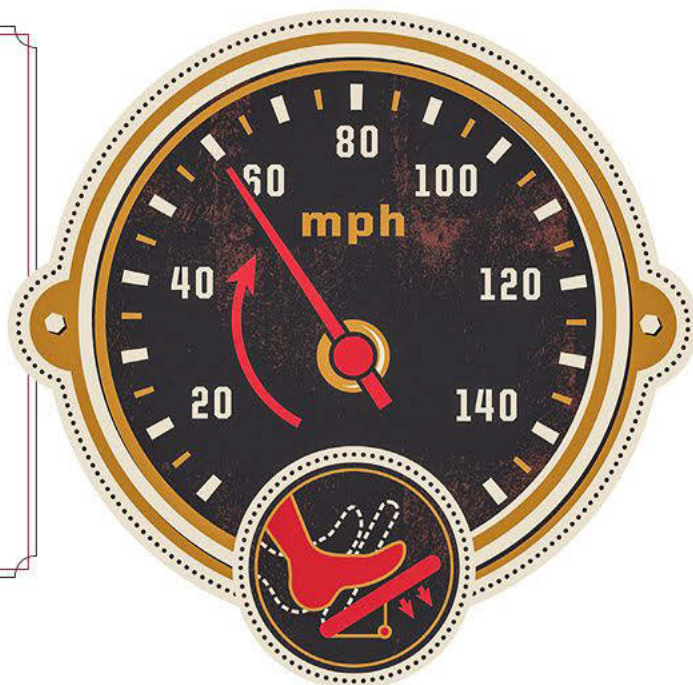
{Q}

Where did we come from?

✱

{A}

Ask your mother.



How is a car's zero-to-sixty time measured? Could I get the same number on my own by flooring it?

THERE IS AS MUCH ART as science in coming up with a new car's acceleration specs, which is a fancy way of saying that carmakers introduce a healthy fudge factor to the numbers, designed to take into account, among other things, the data they think car-magazine testers will report, as well as the times they think consumers will actually achieve. In theory, the zero-to-sixty time you post shouldn't vary much from the published number.

Though there are alternative testing methods—like the lesser known *Thelma & Louise* protocol, in which cars are pushed

over cliffs and tracked with radar guns as they accelerate toward terminal velocity—in practice, manufacturers don't sponsor a single pedal-to-the-metal sprint to determine a car's zero-to-sixty time. Rather, using GPS and other technology, they collect data on acceleration during many test-track outings, in different atmospheric conditions, at different altitudes, with different drivers, etc. These numbers, once suitably crunched, render something resembling an average. Carmakers then publish a time slightly slower than this average, in a nod to the “underpromise, overdeliver” maxim.

{Q} Why are we here?

✱

{A} Ask your father.

Will people ever be able to subsist solely on nutrient-packed pills or powders, as suggested in sci-fi movies?

Keith Richards survived on nothing but pills and powders for years, though that's probably not the sort of thing you're asking about. As far as conventional food substitutes go, *Jetsons*-style meal pills are unlikely to ever get the job done. There's simply no way to cram enough nutrition into a single pill you could swallow without your neck bulging

like a python digesting a pony. If you had all afternoon to funnel down fistfuls of pills, there's some chance you could get enough vitamins, fats, and minerals to keep you alive, but who wants to do that?

Powders, on the other hand, are far more promising food substitutes. Hospitals already use them to feed folks who can't chew, and

a relatively new company called Soylent (a creepy reference to a fictional company that produced a pseudofood containing human flesh in the 1973 sci-fi film *Soylent Green*) markets an array of powders that, when mixed with water and/or fish oil, are said to constitute a relatively complete diet. Mix them with soup and a sandwich and you're covered.

{Q} Why did we evolve consciousness?



{A} The pastrami sandwich wasn't going to invent itself.

How many bathrooms does Air Force One have?

➤ **Good luck finding out.** The commander in chief's airborne-commode count is apparently sensitive information, or maybe so insignificant a fact that nobody's bothered to tally them. Published schematics of the plane appear to depict between five and seven bathrooms. But efforts to obtain a

definitive answer met with no success. We called the White House, who had us call the Air Force. They said they'd never been asked that question before and would not answer it. We called author Robert Dorr, who wrote a book about the plane. He didn't know. He called his sources. They wouldn't tell. There

are fragmentary reports about the quality of the bathrooms—ranging from typical airline-grade in the press section to extra-nice in the presidential zone (Obama's personal can is said to sport two sinks)—but no info on the quantity, though we doubt you'll have any trouble should you be invited aboard.



Do you have unusual questions about how things work and why stuff happens? This is the place to ask them. Don't be afraid. Nobody will laugh at you here. Email greatunknowns@popularmechanics.com. Questions will be selected based on quality or at our whim.

GREAT
UNKNOWN



Does New York City really make better bagels because of the tap water?

YOUR PREMISE, OF COURSE, is correct. New York City does produce superior bagels. Order a “bagel” practically anywhere else and odds are you’ll be presented with a half-done hamburger bun with a hole in the middle, or a mangled pretzel minus the salt, or some other ring-shaped abomination composed of notionally edible Scandinavian mattress foam. This you don’t want.

So why is the Big Apple the bagel champ? Could the long-positd tap water advantage really make a difference? Turns out, yes—though there are other unique-to-New York factors in play. Bagels are simple. Typically they have only four or five ingredients, and one of them is water. New York City tap water, piped in from the Catskill Mountains, is especially pure to start with and is not filtered for sediment, so it contains a unique balance of minerals, which interact with the yeast in the bagel dough to produce specific results, just as the soil in which grapes are grown affects the quality and taste of the wine it produces. One would-be bagel baron in Denver went so far as to analyze New York water and commission special filters to convert Mile High tap water to New York specs.

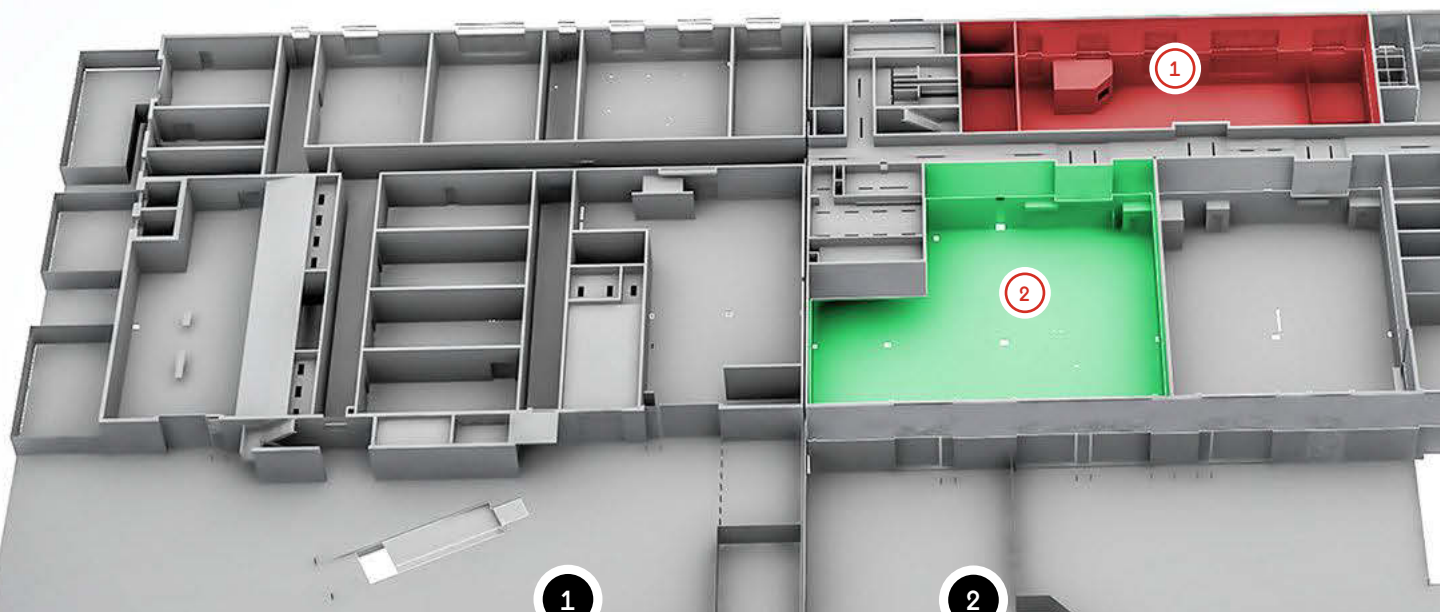
But water is only one factor in New York bagelry. Rising dough, which is a chemical reaction, is also affected by its environment: humidity, the amount of salt in the air, the particular local microorganisms that waft around. For example, according to Jansen Chan, the director of pastry arts at the International Culinary Center, sourdough bread, that San Francisco specialty, results in part from the high salt content in the Bay Area breeze. Technique plays a role as well. Big Apple bagels tend to be boiled longer than the norm, resulting in that famously thick skin that’s a hallmark of New York’s favorite baked goods, as well as of its residents.

THE VIRTUAL GRID

A sprawling high-tech facility in Colorado helps integrate solar power into outdated systems—without causing blackouts or explosions in the process. We got exclusive access to find out how.

THE STATE OF HAWAII could be a brochure for a future powered by renewable energy: Photovoltaic panels are as ubiquitous as swimming pools. But despite being an energy model for the rest of the U.S., Hawaii has had trouble actually using the power the panels provide. During peak hours the sun contributes so much electricity that it threatens to destabilize the entire grid. To help utility companies conquer challenges such as these, in late 2013 the U.S. Department of Energy opened a \$135 million test facility that can simulate almost any

electrical-grid problem. The 182,500-square-foot Energy Systems Integration Facility, on the National Renewable Energy Laboratory campus in Golden, Colorado, is the only place in the country that can perform the megawatt-scale simulations utility companies require if they are to be prepared for the future. “No utility wants to run experiments on a grid while it’s delivering power to customers. They need to keep the lights on,” says associate lab director Bryan Hannegan. Here we explain how four of ESIF’s labs perform solar-energy simulations so your local power company doesn’t have to.



5,300 square feet

When ESIF helped solar-power-systems provider SolarCity and Hawaii’s largest electrical utility investigate their grid-overload problem, the researchers started in the Smart Power Lab. It contains three homes stripped down to the electrical essentials: appliances, an a/c unit, and lights. One is traditional, with no smart devices. Another is an optimized smart house. The third is a hybrid. During the Hawaii test, ESIF tested residential-size smart inverters, machines that can decide when and how to move energy around to prevent the grid from being overwhelmed.



8,600 square feet

To analyze transient power increases on a larger scale, ESIF uses the Power Systems Integration Lab. In this room components like commercial-scale smart inverters, which do the same thing as residential inverters but for solar farms, are tested on their ability to smooth out spikes and direct current to homes that need it or to a battery for storage.



While preparing the U.S. for clean energy, ESIF isn't wasting *any* energy. The building, partially warmed by the supercomputer's waste heat, is certified LEED Platinum.

4



Two screens at 3,540 x 2,790-pixel resolution

This is where designing a utility grid becomes a virtual-reality version of The Sims. When a researcher enters, a set of infrared cameras notes his location and adjusts a 3D visual model of a grid around him. The researcher can then decide that an inverter is not in an optimal location, pick it up, and move it. The room will send the new location to the supercomputer, which will change the simulation in the labs down the hall.

4

3

3

10,000 square feet

Playing with a data set as large as a simulated energy grid requires massive computing power. ESIF's central supercomputer, which can process input from anywhere on the campus, is one of the fastest in the world, performing 1.19 million billion calculations per second. It can quickly scale up the three houses in the Smart Power Lab to simulate a 10,000-home community, then analyze how many inverters would be needed to stabilize it. Researchers can then tweak the parameters, asking questions like: What if everyone in this town had two refrigerators?



A concrete cylinder
explodes under
testing at the
National Ready
Mixed Concrete
Association's
research lab on
April 24.



MAXIMUM
PISTON STROKE

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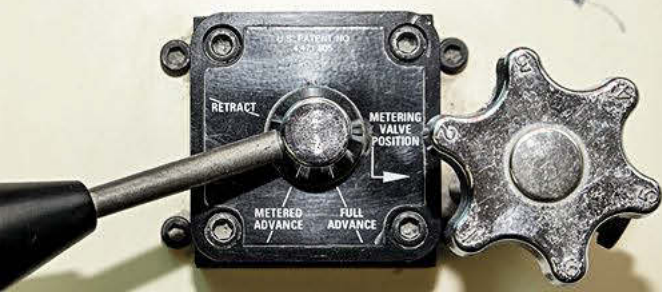
See page 90
to find out
about this
concrete we
blew up.

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MAN HAS TIME FOR INVISIBLE SCIENTIFIC FORCES when he's got a hammer in one hand, a two-by-four in the other, and five nails in his mouth. The questions pop up later, over a beer, looking at the insulation you just installed. How *does* expanding foam work, you wonder. What makes glue sticky? Why is rust bad? We found ourselves pondering questions like this often enough that we asked a few scientists to help us find answers. Some of what we learned is useful. The rest is just cool. But now—at long last—we can get back to focusing on work.

PHOTOGRAPHS BY JEFF ELKINS



Testers

All that stands between a speeding car and a cliff is a concrete barrier—and the National Ready Mixed Concrete Association.

C
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6

CONCRETE IS basically rocks and sand, held together by a paste of water and powder. And yet

we drive over bridge supports without fearing that we'll hurtle into a bay, and we stand at the top of skyscrapers trusting that the floors supporting us will not crumble. As we should. Even low-strength concrete can handle roughly 4,000 pounds per square inch of compressive force. That's a Ford F-150 stacked on every square inch.

That we know this information at all is largely due to facilities like the National Ready Mixed Concrete Association's research lab, which performs strength, reactivity, and freeze/thaw tests (among others) to ensure that concrete can handle the stresses placed upon it. Located in (what else?) a concrete building in College Park, Maryland, the lab tests many of the largest ready-mixed concrete producers in the country.

To learn how concrete works, Popular Mechanics visited the lab and asked the engineers to perform one of their more exciting tests, the

compression-failure test, in which a machine places up to a million pounds of load on a 4-inch-diameter by 8-inch concrete cylinder until it fails, sometimes explosively (see photograph, page 88). The lab agreed to smash ten cylinders they had lying around, ranging from a low-strength mix typically used in pavement to a high-strength mix of the sort usually used in high-rises. The low-strength mix broke at 3,660 pounds per square inch. The high-strength withstood the pressure until cracking and crumbling at 13,080 pounds per square inch.

The difference? Water and

additives, mostly. Though the science regarding concrete strength is complex, it essentially comes down to the cement paste: Less water yields stronger cement, creating tighter bonds between the aggregates and containing fewer tiny air pockets. In strong concrete what finally breaks are the rocks themselves. In low-strength concrete the cement paste typically cracks first.

As some structures from Roman times attest, it's possible for concrete buildings to stand for thousands of years. Modern building practices don't require that degree of endurance: Concrete used to build bridges is designed to last seventy-five years, and that used for residential buildings is made to last fifty. As the U.S. infrastructure erected in the early half of the twentieth century begins to crumble, we'll need to ensure that the materials we use next are strong enough to handle the loads of the next three-quarters of a century. In the meantime premixed concrete will remain as trustworthy as ever. The NRMCA is watching.

— KELSEY ATHERTON



**THE LAB
SUPPLY,
THE LEGEND:
PARAFILM**



Saran wrap sucks. It shreds easily, cuts poorly, and sticks to itself better than it sticks to anything you might want to put it on. Why has no one invented anything better? They have. Parafilm M, a common lab supply you could call the Sealy Posturepedic of plastic wraps, is a paraffin-based film that is made of nontoxic, food-safe materials, conforms to any surface, and won't stick to itself. Scientists often "borrow" it from the lab, but you can purchase it from Amazon or science supply stores.



A CHEF'S GUIDE TO SMOKE POINTS

BY WYLIE DUFRESNE

I LEARNED ABOUT the smoke point of oil by destroying a perfectly good piece of black bass. I was just out of cooking school, and I couldn't get the skin to stop sticking to the pan. The last thing I thought I should do was crank up the heat, but that was the answer: The oil needed to get close to its smoke point, the moment just before it lights on fire.

Approaching this magical smoke point (and staying there) would be simple if all cooking fats were the same, but of course they aren't. Less refined, saturated fats like butter, lard, and coconut oil are packed with enzymes, minerals, and other compounds that create smoke at low temperatures. More refined, unsaturated fats like canola oil begin to smoke at a much higher temperature. The general rule is the lighter the oil, the higher the smoke point. The other general rule is the higher the smoke point, the less tasty the fat.

There's a way around this flavor problem: Sauté in clarified butter. We go through fifty pounds of it a week in my restaurant. Just melt a pound of butter (on the stove, not in the microwave), then scrape off all the white milk fats, and keep what's left in the fridge. You can spoon out a little every time you need to sauté something. Also, it tastes great on popcorn.



Unnecessarily Expensive Test

We wanted to find out what is inside Oatey PVC primer and cement, so we asked a fancy lab.

ONE OF THE goals of science education is to create excited researchers, and

the best way to do that is to let college students play with extremely expensive machines. At the University of Maryland, Baltimore County, a facility for exactly this purpose, the Molecular Characterization and Analysis Complex (MCAC), allows students to use equipment they might not otherwise have access to, such as mass spectrometers worth tens to hundreds of thousands of dollars. We always wondered why Oatey sells dozens of different plastic-pipe cements, so we asked the MCAC to help us learn what is inside Oatey's Purple Primer and Regular Clear PVC Cement. They used four different instruments, worth a total of \$750,000, to find out.

PRIMER

► The main ingredients are solvents—acetone, methyl ethyl ketone, tetrahydrofuran, and cyclohexanone. “Like dissolves like,” says Bill LaCourse, dean of the university's College of Natural and Mathematical Sciences. “I'm sure they worked quite a bit trying to figure out the best ratio of solvents to clean the pipe's surface, take off grease or shellac, and dissolve the PVC pipe itself. The formulation would probably change depending on the density of the pipe, and what type of plastic it's made of.”

► The primer also contains a purple dye, which was difficult to see on the test that identified the solvents because dyes don't turn into gases as easily as solvents do. The researchers used the absorption of ultraviolet light to find the dye by detecting its color.

CEMENT

► Again, the main ingredients here are acetone, methyl ethyl ketone, tetrahydrofuran, and cyclohexanone. The cement, however, contains more tetrahydrofuran than the primer. Tetrahydrofuran dissolves PVC, in this case preparing the pipe to blend with the polymer that is also in the formula.

► This polymer is polyvinyl chloride (PVC), the same as in the pipe itself. Once the pipe is softened, the polymer forms cross-links between the two pieces of the joint. To detect the PVC, the MCAC used a test they invented in-house. It blasts hot nitrogen gas across solid surfaces until particles lift off. “Chloride ions have a unique signature in this test,” says LaCourse. “It helped us instantly identify the PVC.”

— JACQUELINE DETWILER



HOW TO

Stick Stuff Together

USING THE RIGHT GLUE MATTERS. THIS IS WHY.

A GLOSSARY



MECHANICAL BONDS: Hardened glue interlocks with the nooks and crannies of the surface in question.



COVALENT BONDS: Two molecules share electrons.



HYDROGEN BONDS: Molecules that have strong dipoles, or positive and negative sides, align with each other, like magnets.



VAN DER WAALS FORCES: More complicated than hydrogen bonds, but similar. Kind of a transient, moving attraction, like being stuck in traffic with the Dallas Cowboys cheerleaders, in separate cars.

THE BOND

THE GLUE

WHY

WOOD TO WOOD

Polyurethane
Gorilla Glue

➔ After penetrating the wood, part of the glue molecule, called an isocyanate group, makes a **covalent bond** with part of the cellulose in the wood. It also reacts with water in the wood. This reaction gives off carbon dioxide, which is why wood glue sometimes foams and why you need to apply pressure to the joint while the glue cures. Once dry, the glue also forms a network of **mechanical bonds** with the wood.

PLASTIC TO PLASTIC

Cyanoacrylate
Loctite Super Glue

➔ Two different groups in cyanoacrylates allow the water on the surface of the plastic to start the cure. This happens rapidly, often within seconds, making the glue bond to itself and harden. This creates **mechanical bonds** between the porous plastic and the glue. **Van der Waals forces** secure the bond.

CERAMIC TO CERAMIC

Cyanoacrylate
Loctite Super Glue

➔ Again, trace amounts of water on the surface of the ceramic launch a reaction that hardens the superglue. Ceramics have a porous surface, which makes for strong interlocking **mechanical bonds**.

GLASS TO GLASS

Modified silane adhesives
Loctite E-30CL
Hysol Epoxy

➔ Glass is made of silica with a hydroxylated surface that likes to form a **covalent bond** with silane (a silicon atom surrounded by four hydrogens) in the adhesive, creating a strong hold.

COTTON TO COTTON

Polyvinyl acetate (PVA) craft glue
Aleene's Tacky Glue

➔ Groups on the end of the PVA called esters form **hydrogen bonds** with part of the cotton's cellulose. You also get **mechanical bonds** between the porous fabric and the adhesive.

WOOD TO PLASTIC

Cyanoacrylate
Loctite Super Glue

➔ Cyanoacrylate's ability to spread over and penetrate a variety of surfaces makes it ideal to bond unlike materials, but beware: Super-glues are brittle when they harden, and if the materials expand on account of temperature or humidity, the glue can fail. — **MATT GOULET**

With thanks to Connie Howe, senior manager of technical services at the Adhesive and Sealant Council.



SCIENCE FOR COCKTAIL PARTIES

➔ **Sodium laureth sulfate**, an ingredient in soap, is a molecule that has one side that likes water and one side that likes oil. When you wash your hands, the side that likes oil sticks to grease. The other side sticks to the water, and the whole mess goes down the drain.



Breaking Bad's scientific adviser, University of Oklahoma chemistry professor Donna Nelson, on...



DIY CHEMISTRY THAT WON'T GET YOU ARRESTED BY THE FEDS

People use spray window cleaner to clean things other than windows, but I have found it can also spot-clean clothes. I discovered this by accidentally picking up window cleaner one time when I reached for the laundry spray. It worked beautifully, and then I rationalized the result: It's the ammonia in it that does the trick. Ammonia is an excellent general cleanser, and window cleaner is a dilute solution of it. It's frequently great for getting out stubborn stains that some laundry cleaners have trouble with, so you can use window cleaner even if you have spray cleaner on hand. Just make sure you test it on a small sample area first.



Mysteries of DIY Explained

A handyman needn't have all the answers. But here are three you might find useful.

1 How does expanding foam work?

Pulling the trigger on a can of spray foam is about as close as most of us are ever going to get to releasing a genie. A twelve-ounce can produces thick layers of solid foam, the equivalent of about twenty tubes of caulk. How is this possible? Inside the can is a chemical reaction on the brink: Two long-chain chemicals called polyols and polymeric isocyanates have already started reacting, creating a precursor to polyurethane. When you pull the trigger, another chemical, called a hydrocarbon blowing agent, shoots the precursor out of the can, creating bubbles that turn the polyurethane into a foam. Water vapor from the air adds the final piece, curing the foam

into a solid. "We do almost all of the chemistry, and we put it into the can," says Bev Selle, product development leader at the Dow Chemical Company, maker of Great Stuff foams. All you have to do is aim it at the crack in your attic ceiling.

2 Why do my electronics hum?

Whether it was in the adapter aisle at Best Buy or a Greats of the Seventies concert, you've probably heard of AC/DC. Blame the first half for the hum. Alternating current (AC) is the form of electric power that comes out of outlets. It's cyclical, repeatedly reversing direction. In the United States' power grid, AC power reverses sixty times a second, giving it a frequency of sixty hertz.

To be clear, the hum you

hear is not electrons moving. As you may remember from school, an electric current creates a magnetic field. In the case of AC, this field reverses with the same frequency (sixty hertz) as the current. The hum comes from metal bits moving with the field, says MIT electrical engineer Ruonan Han. In appliances that are old or shoddily constructed, loose parts can pick up these vibrations, amplifying the waves until your old TV sounds like it's about to take off.

3 Why is verdigris on copper desirable but rust on iron undesirable?

Much like grandparents on skateboards, most pure metals would rather move to a more stable state than stay where they are. When certain metals come in contact with certain environmental chemicals (in this case, oxygen), they're usually willing to give up electrons just to revert to a more stable mixture. For copper, this creates verdigris, the beautiful turquoise skin of Lady Liberty. For iron, it creates rust, the leprous wheel well of your pickup.

The difference comes down to the compounds themselves. Rust is a porous, inadherent substance that accumulates on iron in clumps. Verdigris is a uniform film that sticks tightly to copper. As rust cracks and flakes, new rust forms on a larger surface area, allowing harmful chemicals in to ruin the iron. Verdigris, on the other hand, protects the metal from future insult. The result: No one takes vacation photos in front of your car's wheel well.

— KEVIN DUPZYK

► **The common name** for the types of molecules that make up Super Glue, cyanoacrylates, is... superglues.



► **Concrete is constantly getting harder.** The reaction that cures it, hydration, will go on as long as the concrete still contains unhydrated cement. For some mixes, this can continue for years.



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HaulMaster
LOT 60497/61899
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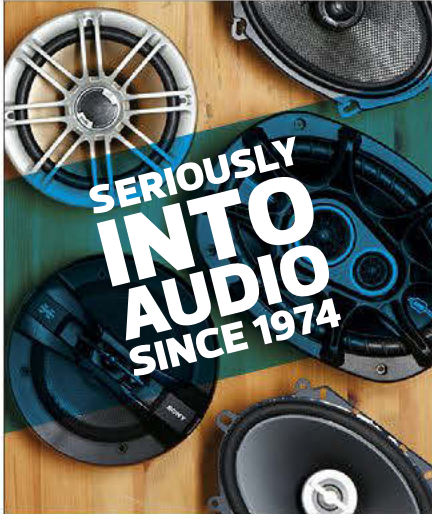
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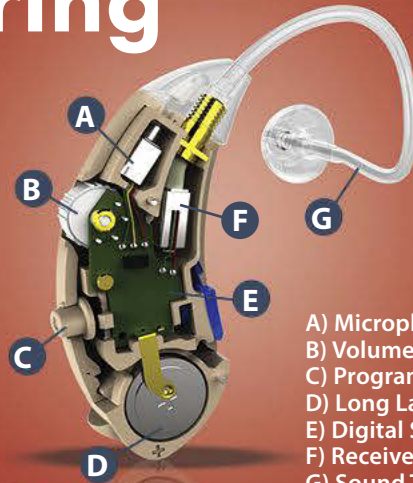
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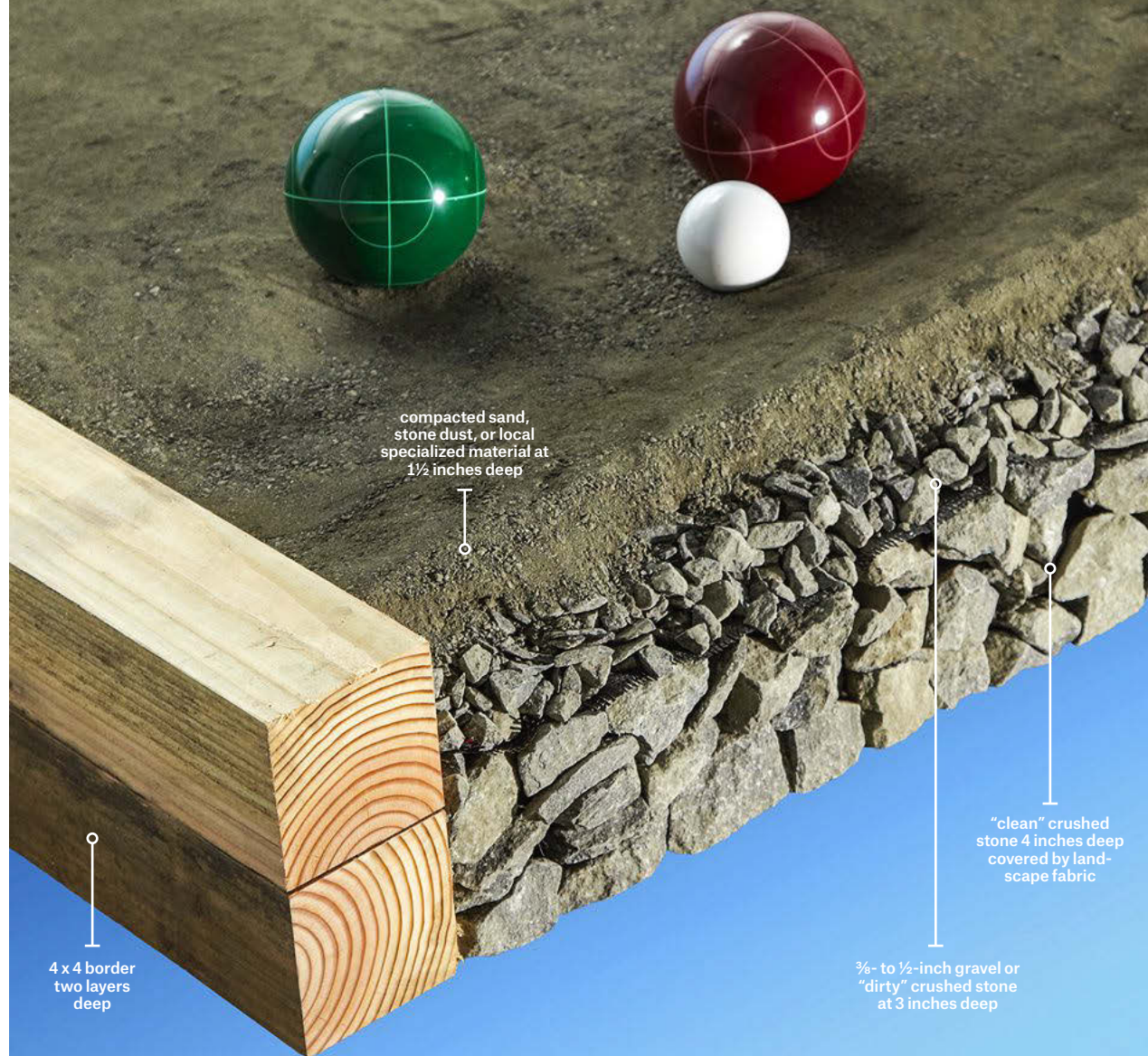
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PROJECT

BOCCE COURT

Building a basic bocce court is pretty simple. It's mostly fun to build, although not every step is fun. But it's always fun to use, bocce being an ancient recreation played on sun-dappled afternoons by weathered Italian men wearing panama hats and drinking jug wine. The construction requires not much more than marking out a big rectangle, some digging, and spreading and compacting granular materials. It's a little work, but a court gives your game the predictability that rolling a ball on a lawn never will.

PLOT THE COURT

First decide how big you want your court. Regulation is 8 to 14 feet wide by up to 91 feet long. A more reasonable size is 8 to 10 feet wide by about 60 feet long. Really, you can make it any size you want. Once you decide the size, add to it the width of its border material. For example, if you will border the court with 4 x 4 pressure-treated lumber, as we did, add about 8 inches to the court's width and length.

Drive a wood stake to mark the first corner, and use a 100-foot tape measure to mark the first long side of the court's rectangle. Drive the second stake. Tie off a bright-orange mason's line stretched tight from stake to stake.

Working from this string line, measure the width of the court and drive a third stake at 90 degrees to the first or second stake. Do the same at the opposite end.

Stretch a second mason's line between

stakes three and four, giving you two long parallel reference lines. An easy way to check for absolute parallel is to work with a helper and stretch a tape measure from either of the lines and swing the end of the tape in a short arc at various points along the rectangle. The crest of the arc is your court width. This is more accurate than simply measuring across because it eliminates the need to measure precisely at 90 degrees to the reference line, which would be a pain. Carpenters, masons, and millwrights have used the swinging measure trick for generations. If the lines are not parallel, adjust one of the lines accordingly.

Measure the diagonals, which should be equal.

Using a can of turf-marking paint, spray the rectangle onto the grass.

DIG

Remove the mason line but leave the stakes. Remove the sod with a flat shovel or rent a turf cutter.

The amount of excavation you do depends on how you build the court. If the ground is rocky and difficult to dig, it makes more sense to build the court up. If the ground is soft and sandy, and digging is relatively easy, dig down 2 to 4 inches, so long as you have somewhere to put the excavated soil or you can use the soil from one part of the court to level off another. This will still put your court slightly above grade, which is good. The lower you build, the more likely your court will become a bocce puddle in wet weather.

MATERIALS

Suppose you were to build a bocce court that had a playing surface of approximately 10 x 60 feet. Here's how you'd estimate your materials. First, to conserve lumber and the amount of cutting you'd do for the border material, reduce the actual playing surface area to 9 feet 5 inches wide by 60 feet long. That way, a 10-foot 4 x 4 could span the width of the court without cutting or waste. You could also use the same 4 x 4s along the length with a minimal amount of cutting.

QTY.	DESCRIPTION	ESTIMATED PRICE
28	pressure-treated 4" x 4"x 10'	\$400
15 cubic yards	aggregate material	\$500 to \$800 delivered
1	roll of geotextile filter fabric	\$55
1	can of landscape-marking paint	\$6
1	miscellaneous fasteners, tools, rentals	\$100 to \$200

GRAND TOTAL, INSTALLED COST, DIY LABOR: \$1,061 to \$1,461

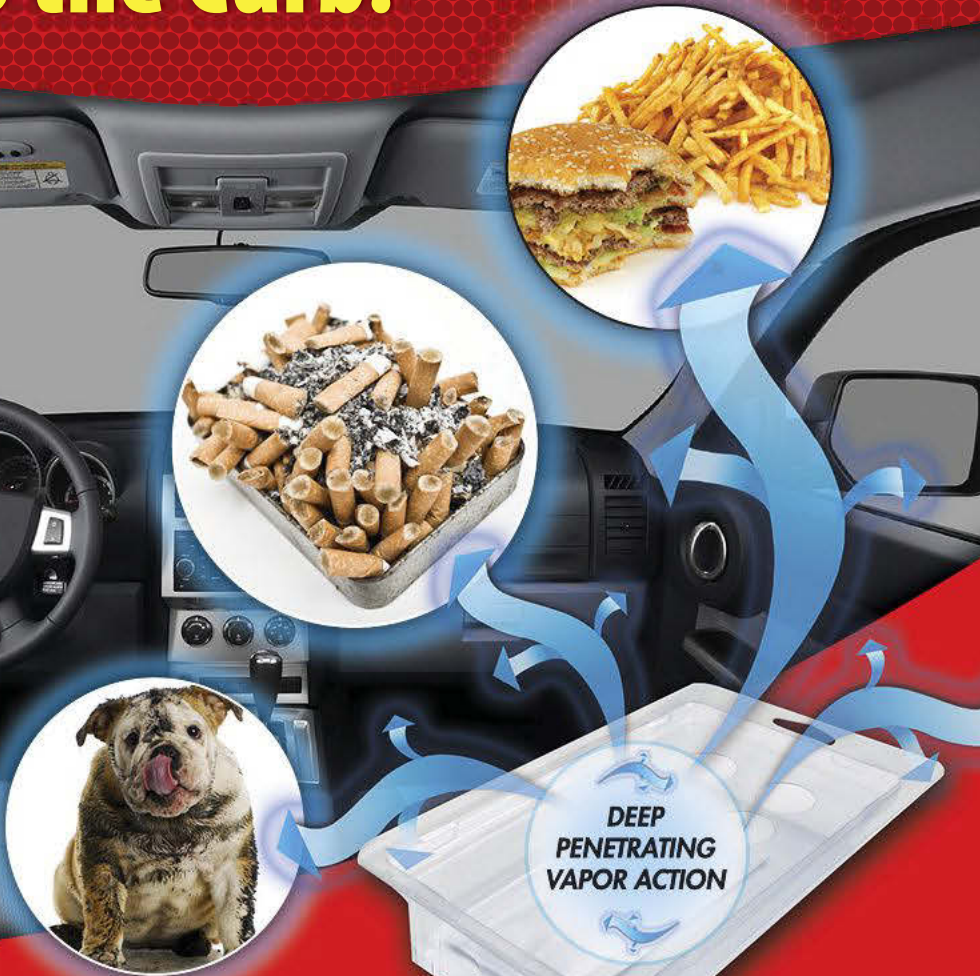
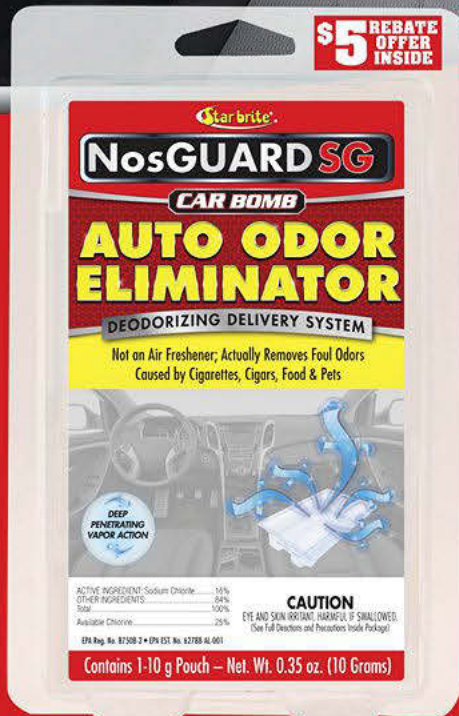
TIP

Use an online bulk-material calculator, found on the websites of landscape supply centers, quarries, and stone suppliers.

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PROJECT

BOCCE COURT

INSTALL THE BORDER

Lay the pressure-treated 4 x 4s in the trench, stacking them two high. Backfill the soil to keep the 4 x 4s in place, and fasten the 4 x 4s together with 10-inch spikes. The hardest part here is maintaining level and straightness. But remember, you’re building a bocce court, not a house. Stretch string lines (from the stakes) whenever you need visual reference to keep the border straight. To keep the materials in plane, use a 3-foot level for short sections. Hold the level to a straight 8-foot 2 x 4 to check longer lengths.

LAY THE COURT

The play area is built in three layers. The coarsest layer is compacted at the bottom and covered with geotextile fabric. The next coarsest material is in the middle, and the finest material (the playing surface) goes on top. The specifics of your court material will depend on what’s available where you live. For example, the bottom layer may be 1-inch washed crushed stone. The layer above that may be $\frac{3}{4}$ - or $\frac{1}{2}$ -inch crushed stone or gravel. Put down the layers in declining thickness. The bottom layer is normally 3 to 4 inches thick, the next layer half that, and the top an inch or so.

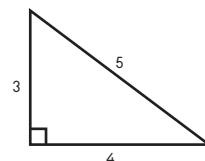
The following materials are recommended for the playing surface itself.

- ▶ **Sand:** Works well, easy to obtain, inexpensive, but it can require careful raking and smoothing, and moist compacting before the match.
- ▶ **Stone dust:** This is the finest crushed stone with dust-size particles blended in. It goes by various names, depending on where in the country you live. Sometimes it’s known by the specification number of the state or county highway department. When compacted, it’s quite firm.

- ▶ **Tennis court clay:** Nice, a little harder to get, a little more expensive, can be purchased through tennis court supply houses on the Web or locally. Har-Tru (hartru.com) is the most well-known brand.

- ▶ **Processed oyster shell:** Many bocce players consider this to be the best surface. The fine, platelike shape of the ground shell helps it to self-level after a rain. It’s a West Coast product that’s shipped directly from the West or from East Coast warehouses (bocce.com).

**HOW TO
MAKE A RIGHT
ANGLE:**
The 3-4-5
Triangle



There are two ways to square one line to another. The first way is to hold a carpenter’s rafter square (a big metal ruler shaped like an L) at the point where the two lines check. That’s okay for a relatively small distance, to ensure a 90-degree corner over 10 feet.

For a larger distance, use the ancient 3-4-5 triangle. If one leg of the triangle is 3 feet, the other 4 feet, and the hypotenuse 5 feet, then one corner will be 90 degrees. The same holds for multiples of that, such as a 6-8-10 triangle.

TIP:

Use a geotextile fabric over the base layer. This prevents fine materials from washing down from above and clogging the air spaces in the coarse material below.

SHORTCUT

THE TWO-LAYER COURT

Parts of the country that don’t see winter frost, have well-drained soil, and don’t have soggy soil conditions are perfect candidates for this type of playing surface. Here you’d go with a layer of fine gravel ($\frac{1}{2}$ to $\frac{3}{8}$ inch) topped by sand, oyster shells, or stone dust.

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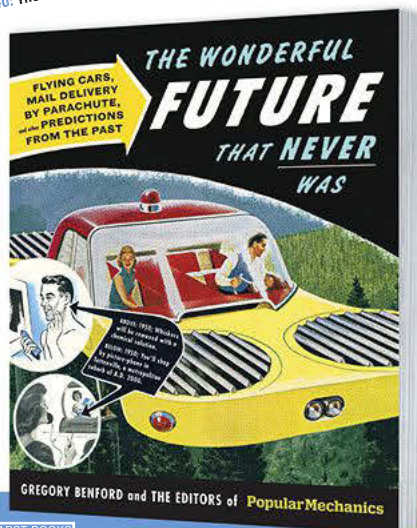
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BACKYARD WATER SHOOTER

A project to build with your children.

Turn the page for the finished product and schematic diagrams

Materials

QTY.	DESCRIPTION
1	1" PVC pipe, 20" long
1	1 1/4" PVC pipe, 20" long
1	1" PVC end cap
1	1 1/4" PVC end cap
1	3/4" PVC plug
	PVC primer and cement
	3/16" drill bit
3	No. 15 O-rings (1" outside diameter x 3/4" inside diameter x 1/8" thick)
	Lubricant such as WD-40 or Vaseline
	Bucket of water

Instructions

● parent only
● parent and kid
● kid only

1. Use a 3/16-inch bit to drill a hole in the 1 1/4-inch end cap. Carefully run the bit through the hole in the opposite direction to remove any burrs that may have formed.
2. Apply pipe cement primer to the inside of the 1 1/4-inch end cap and the last inch of the 1 1/4-inch barrel, followed by a thin film of cement.
3. Push the parts together and twist slightly to distribute the pipe cement evenly. Repeat steps two and three for the end cap on the 1-inch piston pipe.
4. Ream out the other end of the piston pipe with an abrasive sanding drum attached to your drill, until you've made enough room to fit the 3/4-inch pipe plug into the pipe. Approximately 1/4 inch of the plug's stem should extend out of the pipe.
5. Roll two O-rings onto the exposed part of the plug to form a base, then roll the third ring on so that it sits around the first two. (See diagram, next page.)
6. Apply a little lubricant to the O-rings. Pump the squirter gently a few times in a bucket of water to ensure that the rings are seated before taking the toy outside.



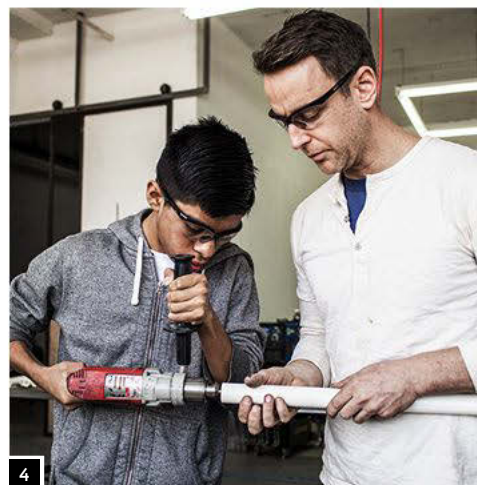
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SEE PREVIOUS
PAGE FOR
INSTRUCTIONS



BACKYARD WATER SHOOTER!

A project to build with your children.

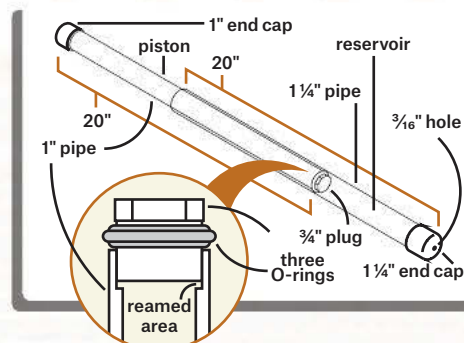
Difficulty: EASY | REASONABLE | HARD
Time: 1 hour **Ages:** 12+

PROJECT NOTES

OUR WATER CANNON is modeled after a version on the amazing website Instructables.com. The abuse-tolerant design means the cannon can be dropped, stepped on, and left outside. You'd have to try hard to break it.

Working with PVC pipe is straightforward. We used a miter saw and an 80-tooth blade that cuts plastic and nonferrous metal, but if you don't have that, you can just as easily use a simple back-saw and a plastic miter box, a \$15 hardware-store item. We experimented a bit with the O-rings too. Our first attempt, No. 13 (7/8-inch outside diameter), was too small, so we moved up to No. 15. For lubricant we used WD-40, but you could also use waterproof silicone grease or even Vaseline.

After the first build, the spray was wide and wasn't shooting as far as we wanted it to. Then we noticed the burr on the inside of the nozzle that had formed when we drilled the hole. A couple of repeat runs through the hole with the bit removed the blockage easily and restored the stream.



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